Final Report

California Energy Commission
Emerging Renewables Buydown Program

On-Site Verification Report
Phases I, II and III

Prepared for:

California Energy Commission
Energy Technology Development Division
1516 Ninth Street
Sacramento, California 95814

Prepared by:

Regional Economic Research, Inc.
1104 Main Street, Suite 630
Vancouver, Washington 98660

RER
Turning Data into Information

June 30, 2002

Table of Contents

List of Tables

List of Figures

Executive Summary

Based upon the electric industry public policy directed by AB 1890 utility restructuring, the Emerging Renewables Buydown Program (Buydown Program) of the California Energy Commission (Commission) was established as one means by which photovoltaics, small wind generators, fuel cells and solar thermal electric systems can be moved toward self-sustaining positions in the marketplace. The Buydown Program does this by providing capital cost reduction incentives to purchasers, lessees, lessors, or sellers of eligible electricity generating systems over a multi-year period to generate market volume and to accelerate learning curves.

As stated in the Guidebook for the Emerging Renewable Resources Account, the California Energy Commission (Commission), is responsible for "conducting random audits of systems that have received buydown payments to ensure that systems were properly installed, are correctly functioning, and are in accordance with the information provided in the reservation request and buydown claim forms."

On-site verifications implemented by Regional Economic Research, Inc. (RER) were commissioned to satisfy this audit requirement. The four objectives of these verifications included: 1) to assure that the photovoltaic and wind systems were installed consistent with information on the customer's Reservation Request and Buydown Claim Forms, 2) to assure that the systems met required building codes and accepted installation practices, 3) to confirm that the systems were operating properly, and 4) to gather market and program information from the buyer.

This report summarizes findings of three phases of verification visits. The total number of verified sites was 132, while the total number of completed systems rebated through the program as of June 2002 exceeded 2,000. Two other reports were produced previously to summarize findings of verification activity. Key dates and verification visit quantities for each of the three reports and verification phases are summarized in Table ES-1.

Table ES-1: Summary of On-Site Verification Activity

Phase	Date of Report	Date of Rebates	Data Collection Period	No. of Sites Verified
I	October 1999	through 2/99	5/99 – 6/99	56
II	June 2000	3/99 – 12/99	5/00	15
III	June 2002	1/00 – 4/02	6/01 – 6/02	61

Site Selection

Site selection strategies for the several phases of verification visits evolved as the total number of completed projects increased. Phase I verification visits covered all systems, (i.e, 100%) rebated through March 1, 1999. Phase II visits comprised a sample of 15 systems selected from 240 projects completed between March 1 and December 31, 1999. The Phase II sample focused on systems installed by dealers and installers that were not represented in Phase I. Phase III consisted of a sample of 61 systems completed between June 1999 and April 2002. Phase III sample selection included some areas of the state that were not visited in Phases I and II, and some retailers whose installations had not been visited. A few of the systems were selected because applications contained contradictory information, or in response to customer complaints. Site visits for particular days were also selected to be in close proximity to each other to increase overall efficiency of verification activities.

The majority of verified systems included photovoltaic equipment. Seven hybrid systems included both photovoltaic and small wind, while one system included wind only. All of the wind systems were installed at residential locations. There were no fuel cell or solar thermal electric systems included within any phase of the verification sample.

Verification Protocol

PV modules were counted and identified by brand and model. Then the inverter brand and model were noted. Orientation and tilt angles of the modules were measured with a compass and inclinometer, and the influence of shading obstructions was assessed. The protocol for wind systems was similar; tower heights were noted, as were turbulence-causing obstructions

A portable digital thermometer measured ambient temperature and a pyranometer was used to measure the instantaneous solar radiation on the plane of the PV array. Output wattage of the system was measured by one or more of several means depending on system features, configuration, and accessibility.

During the on-site verification process pictures were taken of key components of the renewable energy system. After taking measurements and photographs, the verifier interviewed the owner/participant to gather further information regarding the purchase/installation process, and the customer’s perspective. The time required for each verification ranged between 50 minutes and 1½ hours.

The data were recorded on paper forms in the field, and then later entered into Excel spreadsheets. The data forms consisted of six parts: 1) PV or wind system equipment, including mounting system, orientation, and obstructions, 2) the instantaneous power output of the system and coincident environmental conditions, 3) responsible building authority, servicing utility, and system warranty data, 4) photo identification list, 5) verifier comments, and 6) customer comments.

Summary of Findings

Findings summarized below are broadly grouped into those relating to hardware characteristics and performance, and those relating to program processes and participant experiences.

Characteristics and Performance of Verified Systems

A wide variety of system and participant types were represented in the three phases of on-site verifications. The majority of verified systems included photovoltaics only. A smaller number of wind systems were verified. Characteristics and performance of verified systems are summarized below.

System Characteristics

The sites visited ranged from residential sites at an average of about 2800 watts, to large and small commercial sites ranging in size from the 250 kW City Centre installation to an 800 Watt microwave relay station. The total de-rated generation capacity of the 132 verified systems was approximately three-quarters of a megawatt. The majority of the 132 systems were in the residential sector (i.e., 117 of 132). However, the commercial sites accounted for 57 percent (431 kW) of the total Phase I-III verified generation capacity.

More than 70 percent of residential systems were roof mounted. A large majority of systems had no shading or orientation concerns. There were four homes that had what the verifier considered significant shading problems. Eight other systems had manageable, minor “single tree” shade problems. Systems with batteries were the most numerous, consisting of 67 percent of all units. The remaining 33 percent of systems were strictly grid-tie without batteries.

A total of 19 small wind systems were verified at eight residential sites. All but one of the units was very small (i.e., less than 500 Watts), and were installed on 20 to 35 foot towers. All 18 of these small wind turbines were subject to some level of turbulence resulting from nearby obstructions (e.g., home, trees). The one larger wind system was a 10 kW grid-tied model mounted on a 100 foot tall tower, well above any obstructions that might cause wind turbulence.

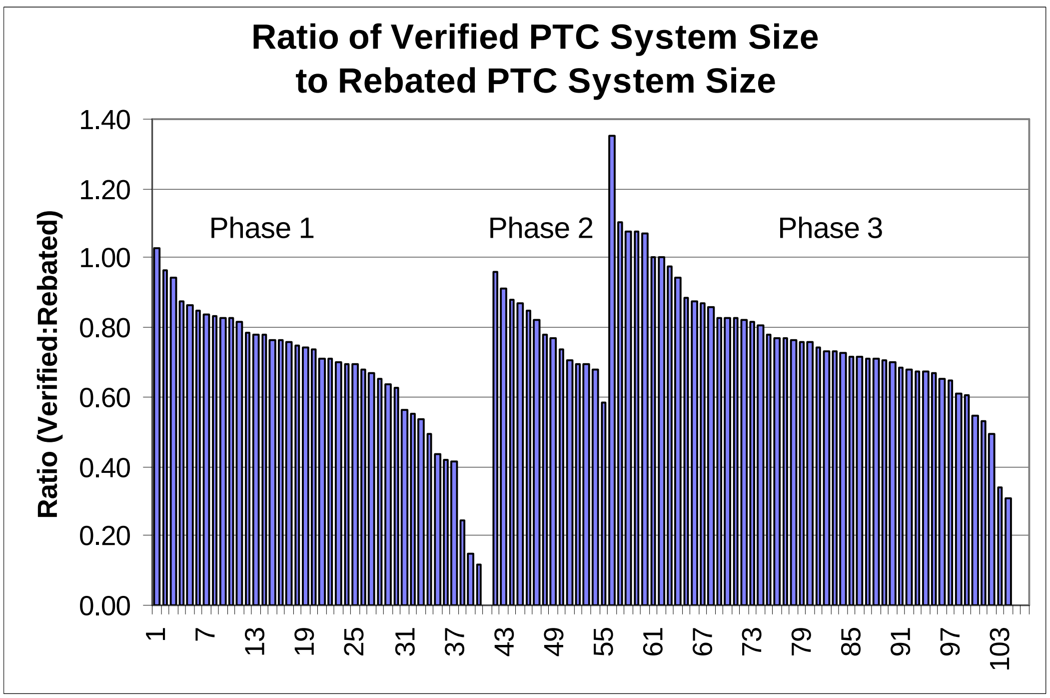
Commercial PV systems that were verified were not as numerous, but due to their larger average size, had combined capacity exceeding that of residential systems (431 kW vs. 317 kW). Seven of the commercial systems were Edison Technologies Solutions (ETS) sites.

These sites included schools and high-visibility public areas. They are fully monitored sites that provide educational and public outreach information. Also included in the commercial groups were two FAA sites containing air navigation equipment. Finally, there were six independent commercial verified sites at manufacturing, motel, service, office, and retail establishments.

System Performance

Electrical output and ambient temperature measurements were taken during verification visits to support assessment of system performance. These data were used to estimate system AC power output at a common reference condition comprising 1,000 W/m^2 plane of array irradiance and 20 °C ambient temperature. The ratio of predicted PTC output to rebated system size was then calculated to enable evaluation of relative system performance. These performance ratios are summarized graphically in Figure ES-1.

Figure ES-1: Normalized PV System Power Output – Residential Systems



Most systems were operational and producing power at the time of the site verification. However, some of the results below 0.6 appear to be associated with system problems. Inverter problems and shading were the factors most often identified as being the explanation for low performance ratios. When there was partial shading on the array, the pyranometer readings were taken in the sunlight rather than in the shade, which leads to calculation of lower performance ratios than would be yielded for unshaded conditions.

Inverters installed in two separate battery-based systems were found not to be in *SELL* mode. This is a problem because when the inverter is not in *SELL* mode it cannot send excess power into the utility grid. Instead, PV system power output is constrained by the state of battery charge and by loads on the critical loads subpanel. In these two instances the customer was unaware of the improper inverter setting, and didn't know there was a problem until the RER engineer brought the operating condition to their attention. Another inverter/battery system utilized an inverter that was not capable of selling power back to the grid. As a result, power output was limited by battery state of charge. This participant reported plans to upgrade to a full-function grid-tied inverter. After the upgrade, system performance is expected to increase substantially. At another site, the inverter was producing about half of the power output that was expected. After significant troubleshooting, testing, and reporting back to the inverter manufacturer by the dealer, the inverter was to be replaced by the manufacturer. What is significant in this case is that this is the second inverter that had to be replaced for this particular PV system. One system was also found to be inoperative for no apparent reason. In this case the customer was advised to contact their installer.

The incidence of apparent problems with 2-inverter systems was high. In one home, one inverter (of two on the PV system) had completely failed, and a replacement inverter had already been shipped and was expected to be received shortly following the on-site verification. At three sites, the inverters were indicating AC output that was erratic and highly variable. One customer reported to the verifier that he had never seen the meter run backwards at the home, even with all the electrical uses at the home shut off. The applicant then demonstrated this effect for the verifier while at the site. These three systems were all two-inverter systems creating a 240 V AC system, which also contained charge controllers and batteries. It appeared *potentially* that the inverters were essentially "fighting" each other. At a fifth dual inverter site, the output was very low. After interviewing the customer, it was revealed that they had experienced significant performance problems with this dual inverter system also.

Performance of wind systems was more difficult to assess. Light, variable wind conditions during the verifications of the small wind systems at seven sites precluded collection of meaningful system electric output measurements. As described earlier, all of these turbines were subject to turbulence effects due to nearby obstructions. The larger wind turbine on the 100 foot tower was observed producing approximately 9.5 kW in a strong, steady wind.

For the non-residential PV systems there were no instances where the performance ratio exceeded 0.9, and only 2 instances where the calculated ratio was below 0.6. One of these systems experienced partial shading during the verification visit, while the other was a small grid-independent battery-based system, the instantaneous output of which is limited by battery state of charge.

Program Processes and Participant Experiences

Findings related to the audit aspect of the verification visits are summarized below, along with highlights of the participant/owner interviews.

Compliance with Buydown Program Guidelines

No significant deviations between expected and observed hardware were noted in previous verification reports covering Verification Phases I and II. During the third phase of verifications several deviations were observed. In two instances the PV module make/size were different; one of the systems was 207 Watts larger than expected, while another was 70 Watts smaller than expected. At four of the 61 systems verified during Phase III, the observed inverter was different from the inverter expected based on review of program files. These inverter differences are attributable to inverter performance/availability problems, and design changes. In none of these four cases where inverters were not in agreement with program records were the program participants dissatisfied with the exchange, and the impacts on system sizes and rebate magnitudes were minimal.

If large numbers of participants objected to verification visits, then one might suspect that actual system configurations differed from those represented on application and claim paperwork by program participants and system retailers/installers. Throughout the three phases of verification visits there were no occasions when this was suspected. There were instances where verification visits could not be scheduled due to vacation and other schedule conflicts, but in these instances program participants generally offered to allow cursory, unattended inspection, or suggested another date/time more convenient for their schedule.

Participant Feedback

Motivation for Buying System. Desire to improve the reliability of electricity supply was a primary motivation for many program participants. Many of the Phase I homes are located far from substations and on the “end” of a radial distribution circuit. Many customers included in subsequent verification phases experienced electric supply disruptions as a consequence of recent upheaval in Western markets for electricity in California. The proportion of residential participants installing systems with batteries stayed relatively constant (>50%) across the three verification phases. A much smaller percentage of non-residential systems included batteries (3 of 15, or 20 percent).

A second major self-reported motivation was environmental consciousness. Concern for the environment was the reason for installation most often cited by participants whose systems were verified during Phase III. However, during the third phase of verifications, increasing numbers of program participants began to cite “concern over the cost of utility power” as a reason for system installation. During Phase I, only 3 of 56 (5%) mentioned this factor, as compared to 15 of 26 (58%) of those verified during the summer of 2002.

Local Utility. Only a couple of homeowners reported that they had experienced technical interconnection problems with the utility. By far, the largest area of complaint from the PG&E customers whose systems were verified during Phases I and II was the length of time that it took to get their billing and accounting information correct. During Phase III verification visits, twenty-five residential system owners provided feedback on their experience with their utility. Twenty-two of these systems were in the PG&E service territory. Fifteen reported having had a smooth experience with the utility while 10 reported having had a bad experience. Complaints reported during Phase III verification visits were similar to those noted during verification Phases I and II.

Local Code/Building Officials. Most customers whose system was installed by a dealer/installer did not have direct interaction with the local code officials, so provided no feedback on this aspect of the installation process. Among those customers providing feedback, the most common report was that local permitting and inspection authorities were relatively unfamiliar with the technology and its unique code/design issues. Several participants who installed their own system reported taking an active role in helping familiarize the permitting and inspection staff. According to participant reports, owner-installed systems were generally not subjected to rigorous review by local building inspectors.

Dealer and/or Manufacturer. Almost all homeowners interviewed during verification Phases I and II, reported excellent relationships with their equipment suppliers, dealer, and installer. Many made highly complimentary statements describing how the dealer "took care of everything" and they had little to be concerned about. Rare exceptions involved cases where the dealer/installer provided insufficient information concerning system performance, operation, or troubleshooting.

Several Phase I and Phase II customers were very upset over their experience with Trace Engineering (now Xantrex), a manufacturer of power inverter systems. In the cases of two systems that were significantly under-performing, the customers reported significant lack of responsiveness from the company in receiving troubleshooting assistance. Trace personnel were reportedly extremely difficult to contact, and were often of limited help. In both cases, the customer was very pleased with their dealer/installer/supplier, and how they were taking significant steps to communicate with Trace.

Customer feedback gathered during Phase III verification visits included substantial numbers of reports of both very good experiences with dealers as well as rather poor experiences. Twenty-four of the customers had positive things to say about the performance of their retailer/installer, while twenty-one had negative things to say. Complaints covered a broad range, including: poor customer service, poor communication, poor instructions, excessive price, underperformance, improper wire sizing, poor attention to detail, and lack of expertise. Two participants cited the *need for better system rating information*; two others suggested that *all systems should be required to include some provisions for local performance monitoring*. Several Phase III participants reported having problems with the new Advanced Energy MultiMode inverter. Three such inverters were reported to have failed, necessitating replacement. In these cases, participant criticism was directed largely at the local dealer or installer who recommended the unit, rather than at the manufacturer itself.

California Energy Commission. Participant feedback on the Commission and the Buydown Program was almost uniformly complementary. Many customers reported that the Commission's program enabled them to turn a long-standing aspiration into reality. One customer thanked the Commission specifically for "going to bat for him", helping make headway with a utility that was going to inappropriately charge a large dollar amount for a new meter to be installed. Numerous enthusiastic program participants suggested that the Commission should do more marketing and advertising to promote the Buydown Program. These participants were particularly committed to the environment, and felt that the program was not sufficiently promoted through media and other means.

The most significant criticism of the Buydown Program concerns the Buydown incentive taxability. Six participants stated that they were upset (from mildly upset to very angry) that the Buydown incentive was taxable, and that the Commission did not make this point clear enough on program forms and promotional materials. Other minor problems encountered by program participants on a more limited basis involved long paperwork turnaround time and misplaced rebate documentation. Overall, Buydown Program participants were very satisfied with the program and the Commission.

Conclusions and Recommendations

To date, three rounds of verifications have been completed. A total of 132 sites were visited from May 1999 through June 2002. A number of conclusions and program recommendations are indicated by this experience, as described below.

Conclusions

Conclusions resulting from the three phases of on-site verification visits are summarized below:

Program Guidelines Compliance

- To date, there has been very close agreement between hardware observed in the field and hardware descriptions indicated in program documentation and the program tracking system. The few exceptions appeared to represent modifications of convenience as opposed to attempts to use deception to collect rebate funds. The incidence of these exceptions appears to be increasing as Program activity increases, however.

System Performance

- Information necessary to establish realistic system performance expectations and to assess actual performance is lacking. The weather-sensitive nature of system performance contributes to the difficulty of translating component nominal rated performance information into realistic estimates of system performance. Lack of reliable system performance data increases the risk that program participants will be disappointed with the actual output of their system.
- Inverter reliability and performance have considerable room for improvement. Reports of inverters being 'dead on arrival', failing shortly after installation, requiring component upgrades, or operating poorly in 2-inverter systems continue to be received.
- The siting of small wind systems less than 1 kW tends to depart significantly from standard rules of thumb. Short towers (< 50 feet) located in close proximity to turbulence-causing obstructions were the norm rather than the exception for the verified systems.

Participant Feedback

- While reliability and environmental considerations continue to represent important motivating factors for system installations, concerns over the cost of electricity from traditional sources is an increasingly important factor. These customers are likely to be particularly concerned about actual system performance relative to expected performance.
- Utility relations are an important area of concern for program participants who report difficulty completing the interconnection process, transitioning to new rates, and obtaining information from utility representatives. Program participants were particularly concerned about phone messages to PG&E not being returned.
- The level of familiarity of local permitting and inspection staff with small, renewable distributed electric generation systems is generally minimal. Program participants routinely report that the individual performing the inspection "didn't know what they were looking at".
- Participants are generally very happy with the Buydown program and would like to see it promoted more aggressively. With only rare exception, program participants report that they would not have installed a PV or wind system in the absence of financial support from the Buydown program. The lone area of dissatisfaction concerns the issue of incentive taxability. The incidence of dissatisfaction related to this issue appears to be increasing.

Recommendations

There are several principal recommendations that can be made to the Buydown Program's implementers based on findings of this multi-year verification task:

- The Commission should continue its program of on-site verification visits. These visits provide information necessary to provide assurances that program funds are being spent responsibly. During the third phase of verifications several minor discrepancies between actual and claimed system details were observed. An on-going, limited program of on-site verification visits is an effective strategy for monitoring, and ultimately resolving, these problems.
- The Commission should increase the visibility/clarity of information and disclosures related to the possible taxability of rebates. The continued incidence of complaints about rebate taxability suggest that existing messages should be made more clear and more prominent. The message could be made more prominent by including it on the Reservation Request Form. The clarity of the message about potential taxability could be increased by adding some additional description of the issues and options to the Program Guidebook.
- The Commission should develop and/or disseminate information related to siting and performance of small wind systems. There would be great benefit in collecting actual energy production information from a sample of small wind systems and making this information available to prospective program participants.
- The Commission should develop and/or disseminate information related to actual performance of PV systems. Findings from the monitoring study or elsewhere should be used to develop information relating rebated size to actual expected system power output. This information could be added to the Consumer's Guide, or presented in a short document posted on the Commission's web site.
- The Commission should require some type of local/easy access performance indicator (preferably kWh) for each system approved under the Program. Participants with systems lacking such an indicator may not know when or how well their systems are working, or under what conditions they should call their installer for service.
- The Commission should continue its programs of training for local permitting staff, inspectors, installers, and customers.

1

Introduction

1.1 Overview of Buydown Program

Based upon the electric utility industry public policy directed by AB 1890, the California Energy Commission's (Commission) Emerging Renewables Buydown Program (Buydown Program) was established as a means by which photovoltaics, small wind generators, fuel cells and solar thermal electric systems can be moved toward a self-sustaining position in the marketplace. The Buydown Program does this by providing capital cost reduction incentives to purchasers, lessees, lessors, or sellers of eligible electricity generating systems over a multi-year period.

Installation verification requirements for the program are summarized in the Emerging Renewable Resources Account Guidebook. Namely, the Commission is responsible for "...conducting random audits of systems which have received buydown payments to ensure that systems were properly installed, are correctly functioning, and are in accordance with the information provided in the reservation request and buydown claim forms." The On-site Verification Task, implemented by Regional Economic Research Inc., was commissioned to satisfy these requirements.

There were four objectives of this verification process. The first was to assure that the grid-tied renewable energy system installations were consistent with the information contained on the customer's incentive Claim Form, particularly with regard to PV module and inverter models and quantities. Second, to assure that the installed systems met building codes and accepted industry installation practices. Third, to confirm that the installed systems were operating properly. The final objective was to gather market and program information about the buyer, the installed system, and the purchase and installation processes.

Three phases of verification visits were implemented. The total number of verified sites was 132. Key dates and verification visit quantities for each of the three phases are summarized in Table 1-1. The total number of completed systems rebated through the program as of June 2002 exceeded 3,000.

Table 1-1: Summary of Verification Activity and Reports

Phase	Date of Report	Date of Rebates	Data Collection Period	No. of Sites Verified
I	October 1999	Through 2/99	5/99 – 6/99	56
II	June 2000	3/99 – 12/99	5/00	15
III	June 2002	1/00 – 4/02	6/01 – 8/01 1/02 5/02 – 6/02	33 2 26

The majority of verified systems included photovoltaic equipment. Seven hybrid systems included both photovoltaic and small wind, while one system included wind only. All of the wind systems were installed by residential participants. There were no fuel cell or solar thermal electric systems included in the verified sample.

2

On-Site Verification Process and Procedures

2.1 Planning and Scheduling

Phase I verification subjects were selected from the Commission database as all (100 percent) of those photovoltaic installations that were completed as of March 1, 1999. Phase II subjects were a sample of 15 (6.25 percent) selected from 240 projects completed between March 1 and December 31, 1999. Phase III subjects consisted of a sample of 61 systems completed between June 1999 and April 2002.

The primary sampling criteria for selecting sites in Phase II was installations by dealers and installers that had not had installations verified in Phase I. A secondary criteria was to verify installations by dealers who were under-represented in Phase I verifications in proportion to their total number of installations. The Phase III sample included a few systems with rebate applications containing ambiguous or contradictory information, and sites installed by dealers whose systems had not been visited in past evaluations. Other selection criteria included equipment size/type/configuration diversity and geographic diversity. The sample was also designed to include a substantial number of owner-installed systems, and systems of various sizes.

Two verifiers were employed in the Verification task – one was assigned the Northern and Central California (PG&E) participants, and the other was assigned the Southern California (SCE/SDG&E) participants. For the initial budget and time assessment, sites were organized into 5 geographic/utility areas: PG&E/Bay Area, PG&E/Sierra & Central Valley, PG&E/Central Coast, SDG&E/San Diego, and SCE/Los Angeles Metroplex. The areas were selected to include groups of installations that could be verified within a week, working out of a specific geographic center. For the actual execution of the visits though, the verifiers further subdivided the sites in these regions into optimum “one-way” or “circular” travel itineraries and attempted to schedule “clumps” of participants in order to minimize travel and limit backtracking. For weekly visits, a goal of 10 to 16 participants for each five-day week was typical. For daily visits, a goal of 1 to 4 participants was typical, depending on the proximity of “clumped” sites. The distribution of verification visits across utility areas is summarized in Table 2-1.

Table 2-1: Number of Verification Site Visits by Utility Area

Phase	PG&E	SCE	SDG&E	Total
I	38	17	1	56
II	15	0	0	15
III	42	9	10	61
Total	**95**	**26**	**11**	**132**

Each participant received a letter of introduction signed by the Commission's Program Administrator. This informed the participant of the purpose of the verification visit and the name of the person who would be calling on them. The appropriate verifier then followed up with a telephone call to each participant to set up the verification appointment. It is worth noting that this recruitment process worked very well. Participants were very cooperative and approximately 80 percent were available for scheduled appointments in an optimum travel itinerary. In fact, participants seemed to go out of their way to accommodate the verifier's optimum schedule. We believe that the letter of introduction was one of the reasons for this exceptional reception and accommodation.

2.2 Verification Procedures

The objectives of the on-site verifications were to 1) assure that the participant had installed what was on the Reservation Form, 2) assure that the system was working properly, 3) take site verification photos, and 4) interview the participant/owners to gather marketing and satisfaction anecdotal data.

Upon arrival at the building, the verifier met the owner/participant and explained what he was going to do. In some cases, the owner would choose to accompany the verifier to see what he was doing, and in other cases, the owner chose not to, but let the verifier perform the technical tasks.

First, all modules were counted and identified by brand and model. In many cases the verifier could not physically verify the brand/size of the module because the branding and nameplates were inaccessible. Alternative, secondary approaches used to verify modules included comparison of observed dimensions and designs (e.g., poly-crystalline versus amorphous) against manufacturer catalog specifications. Next, the inverter brand and model were noted. Orientation of the modules was determined by means of a compass, or if obvious due to known street orientations, then this was noted. The tilt angle of the modules was then determined by inclinometer placed on or in-sight of the module angle.

A portable digital thermometer was placed nearby in a shady spot to measure ambient temperature. During a portion of Phase III verification visits an infrared thermometer was used to measure module temperatures directly. A LiCor pyranometer was then used to measure plane of array solar radiation. The pyranometer was connected by a precision resistor to a standard Fluke 73 or 179 multimeter to measure solar radiation in mV, translatable into Watts/m^2 by means of a calibration multiplier.

Measurements of the output wattage of the PV array were taken as simultaneously to the solar radiation and temperature measurements as possible. This was done by one or several means. If the inverter had an accurate meter displaying the AC output watts, then this was noted. To supplement or provide a sole reading, a Hall Effect "amprobe" was inserted around the PV array or inverter output wires to measure current, and the multimeter was used to measure voltage. During a portion of Phase III visits a Fluke 43B power quality analyzer was used to measured DC and/or AC power directly. At times, therefore, the cover was removed from the inverter system, combiner box, or disconnect switch to reach the appropriate wiring for measurement.

Verification of small wind systems entailed confirmation of system installations and operation (when wind conditions during the visit allowed). System owners were able to provide information about tower heights. The verifier noted presence of topographic or other obstructions potentially influencing turbine performance. Measurement of the output wattage of the wind turbines was done in a manner similar to that described above for PV arrays (when wind conditions allowed).

During these measurements and at appropriate times during the visit, pictures were taken with print film camera, slide film camera, and/or digital camera. During Phases I and II these different format options were provided to provide flexibility for the Commission to be able to select a format appropriate for making duplicates, converting into electronic form, or use in educational presentations. Phase III photography was limited to the digital format.

After taking and noting all of the technical measurements as well as taking photographs, the verifier returned to the owner/participant for the interview. The key questions that were asked dealt with a) permission to use any images taken at the site, b) the participant's experience with any of the "players" in the PV purchase and installation process (namely the dealer, installer, utility, and building officials), and c) any comments the customer wanted to make. Generally, the comments solicited were any that might relate to helping change or market the Buydown program.

2.3 Description of Data

Data were recorded manually onto the Verification Form while on site and later entered into an Excel spreadsheet for easy summary and analysis.

The Verification Form (See Appendix D) consisted of six parts. In the first part, the verifier noted the actual models and sizes (number of modules) of the photovoltaic equipment. With the Reservation form in-hand, the verifier would enter the included information. From there, a determination was made as to whether the equipment information given on the reservation form was consistent with the field observations. The spreadsheet calculated the rated output expected under PTC conditions, which is also the basis of the Buydown amount.

This first portion of the Verification Form also contains entry spaces to note the type of mounting system (e.g., roof, tracking) and the orientation (i.e., azimuth, tilt) of the plane of the PV array. In the case of multiple orientations by different parts of the array(s), these orientations and number of modules were recorded. The verifier also provided his judgment of the appropriateness of the PV array orientation relative to good practice. Any shading of the array by trees or other obstacles was noted (in the field provided), with the verifier providing his opinion as to the importance of such shading.

Part Two of the Verification Form records the wattage output of the array and the actual environmental conditions observed by the verifier at the time the output wattage was recorded. The method for recording output wattages was described earlier. The verifier also made notes as to any unusual observations with the output of the array (variation, erratic outputs). This includes solar radiation in Watts/m^2 and ambient temperature in degrees Fahrenheit. In the case of multiple arrays with different orientations, the solar radiation on the plane of each array was measured and recorded. When this radiation was recorded in the database, the number recorded is the weighted solar radiation based on the number of modules at each orientation. In the case of tracking arrays, again, the radiation on the plane of the array was recorded. There is a final space for the verifier to note his judgment as to whether the array(s) are putting out power consistent with temperature and radiation conditions.

Part Three of the Verification Form records the responsible building authority from which any permits and inspections were derived. NOTE: Because a copy of all permits had been sent into the Commission in order to get the Buydown payment, there was only limited attempt to ask the participant to display his permits. The utility meter was checked to confirm that the customer was indeed grid tied. The name of the utility is given in some spreadsheets. Finally in this section is a space to note whether or not the customer received the Commission-required five-year written system warranty.

Part Four of the Verification Form records the subject of any photos taken at the site. These photos are listed by subject/site with cross-reference to a photo number. Prints, slides, and digital images are identified by their unique number.

Part Five records any further items of note or interest by the verifier. Explicit spaces are provided to note the customer's interest in participating in any Commission PV site data monitoring program, and the verifier's opinion as to whether it might be a good site. The customer's approval for pictures to be shown on the Commission Web site is also noted in this section. Other observations about the customer, whether or not the system has batteries included, and other notes of concern and interest are noted here.

Part Six is where the customer's comments are recorded. These are in response to the verifier's specific questions about the customer's interaction with other stakeholders, and the customer's self-stated motivating factors in buying the system. Other "free-form" comments are recorded here. NOTE: Because these are the customers' answers and comments in a face-to-face conversation, responses could deviate from those collected using an anonymous survey.

3

Characteristics & Performance of Verified Systems

3.1 Characteristics of Verified Systems

A wide variety of installations were represented in the three phases of on-site verifications. The sites visited ranged from residential sites at an average of about 2800 watts, to large and small commercial sites ranging in size from the 250 kW City Centre installation to an 800 Watt microwave relay station. The vast majority of verified systems were photovoltaic systems. A smaller number of wind systems were verified. Most, but not all, of the verified wind systems were installed along with a photovoltaic system in a hybrid configuration. The systems were installed in a variety of surroundings encompassing everything from the urban coastal environment of Santa Monica to the remote, rugged backcountry of the Sierra Nevada foothills.

The total de-rated generation capacity of the 132 verified systems was approximately three-quarters of a megawatt. The majority of the 132 systems were in the residential sector (i.e., 117 of 132). However, the commercial sites accounted for 57 percent (431 kW) of the total Phase I-III verified generation capacity. Site verification activity is summarized in Table 3-1 by sector.

Table 3-1: Verification Activity by Sector

Sector	Number of Sites	System Capacity kW	System Capacity % of kW
Residential	117	317	42%
Non-Residential	15	431	58%
Total	**132**	**748**	**100%**

Residential

Selection of sites for Phase II and III verification visits was based in part on whether or not the contractor's systems had been visited previously. In addition to targeting systems installed by contractors new to the program, substantial numbers of owner-installed systems were also selected. The breakdown of owner- versus contractor-installed residential systems is summarized in Table 3-2.

Table 3-2: Installer Summary – Residential Systems

Phase	N		Percentage %	
	Owner	Contractor	Owner	Contractor
I	13	32	29%	71%
II	3	12	20%	80%
III	16	41	28%	72%
Total	**32**	**85**	**27%**	**73%**

There were a number of residential PV system configurations, both electrical and structural, that were utilized for rebated systems. The structural configurations for residences were roof mount (flush, small offset, or seasonally adjustable), pole mount with automatic tracking, pole mount without automatic tracking, ground rack mount, integrated roof (shingle), and patio cover. The distribution of mounting systems found at the verified residential sites is summarized in Table 3-3.

Table 3-3: Distribution of Residential PV Mounting Systems

Mounting Type	Number of Systems
Roof mounted	86
Tracking System	14
Pole	8
Ground	8
Integrated Roof (shingles)	1
Open structure “covers” (e.g., Patio)	1

Customers mostly chose their existing roof tilts/orientations as the plane of their roof-mounted systems. There were eleven systems on sloped roofs in which a fixed roof rack system was employed to “tilt up” the modules to a more favorable tilt/orientation other than the roofline. Orientations included North, South, East, and West, but approximately one-third of the arrays (part or all of modules) were +/- 45 degrees or more off South. Sixty percent of the residential roof, shingle, and patio systems were oriented within 20 degrees of South.

The large majority of systems visited had no shading or orientation concerns. There were four homes that had what the verifier considered significant shading problems. One home is located within a pine forest with substantial morning and afternoon shading, another other has a large pine tree shading the array from 1 p.m. on. A third residential system is shaded by trees and a radio antennae tower, while a fourth was affected by mid-day shading from a tree located directly south of the array. It is yet to be determined the effect that this shading has on the annual performance of these systems. Eight other systems had manageable minor "single tree" shade problems. Three customers indicated (without prompting) that they were planning to remove or trim the trees that shade the PV array. It is yet to be seen if this will really be addressed by customers.

Several basic electrical configurations were observed, based primarily on the input voltage of the inverter. These were the 48 V DC input type inverters (Trace 4048/5548 and Advanced Energy MM-5000 battery-based models, and Trace SunTie and Advanced Energy GC-1000 grid-tied models), the Omnion +/- 150 V DC inverters, and the SMA 300-400 V DC inverters. In the dual inverter systems, many were tied together to produce a 240 V AC input to the home breaker panel.

The market for inverters evolved during the period during which verification visits were completed. None of the battery-less inverter models verified during Phases I and II remained on the market when Phase III verification visits were completed. One manufacturer opted not to redesign their inverter to satisfy revised UL listing requirements, while another introduced products designed specifically for battery-less operation. During Phase III verifications new [to the program] inverters designed for operation with and without batteries were observed.

For residential site visits, systems with batteries were the most numerous, consisting of 67 percent of all units. Most of these battery units were 48 V DC systems. Included with the battery systems were the standard charge controllers (almost exclusively Trace C40 Controllers) and the transfer switches required to switch house circuits off grid in case of utility power outage. The remaining 33 percent of systems were strictly grid-tie without batteries. Residential PV system sizes and battery storage incidence are summarized in Table 3-4. A larger percentage of smaller systems included battery storage. The majority of PV systems were sized between 1 kW and 5 kW.

Table 3-4: Summary of Residential PV System Sizes

Rebated PV System Size	Number of Sites	Portion of Systems with Battery Storage
0 to 999 Watts	18	78%
1,000 to 4,999 Watts	85	68%
>= 5,000 Watts	13	46%
Total	**116**	**67%**

A total of 19 small wind systems were verified at eight residential sites. All but one of the units was very small (i.e., less than 500 Watts), and installed on a 20 to 35 foot tower. All 18 of these small wind turbines were subject to turbulence resulting from nearby obstructions (e.g., home, trees). The larger wind system was a 10 kW grid-tied model mounted on a 100 foot tall tower, well above any obstructions.

Non-Residential

Commercial installations visited were primarily located in Southern California in the SCE service territory. Commercial/industrial mounting schemes included roof rack mounts, ground rack mounts, pole mounts, and open structure covers. Commercial applications, although limited in number, offer an excellent potential for PV applications, not only for distributed energy generation, but also for their secondary, non-power production benefits. Commercial applications included amusement parks, shade structures for autos and people, remote microwave relay stations, office and retail buildings, and a hotel as summarized in Table 3-5.

There were three distinct groups of commercial sites: Edison Technology Solutions (ETS) sites, Federal Aviation Administration (FAA) sites, and independent sites. The parameters of these groupings are discussed in the following sections.

Edison Technology Solutions Sites

The observed concentration of commercial sites in the SCE territory is a direct result of Edison Technology Solutions' "Solar Neighborhood Program." Through this program, ETS functioned as a facilitator between the customer, the various funding agencies, and the solar designers/installers. Brief descriptions of all ETS sites visited are listed below:

- **UCI, Engineering Building.** This UCI facility is home for the National Fuel Cell Research Center (NFCR). The standing-seam construction PV panels are mounted on a large structure that covers what was supposed to be an outdoor lab area for solar energy experiments. The 5.2 kW PV system is mounted on the back of the building and it is visible from the main access road to the engineering building and parking areas. Numerous tours and seminars are conducted here, providing extensive exposure for the system. However, UCI site personnel have nothing to do with day-to-day system operation, and there did not appear to be any student involvement either. This was in contrast to the attention focused on the high-profile fuel cell research being done at UCI in the same building, illustrated by the presence of a computer monitor in one of the hallways (see photos in Appendix C for this site) which displayed complete real-time operation parameters for an operating fuel cell.
- **Knott's Berry Farm.** There are two roof-mounted systems here; a very large array (28 kW) which is mounted on a building in the "working area" of the amusement park, and a much smaller array (1.5 kW) which is mounted on a building within the park that is used for scientific exploration classes. The larger system is behind-the-scenes and can not be seen by the general public from the amusement park.

Table 3-5: Summary of Verified Commercial Sites

Phase	Business Name	Location	Description	Rated Watts
I	Santa Monica Pier (ETS)	Santa Monica	Roof-mounted, five mostly very large arrays	42,456
I	Santa Monica Civic Auditorium Parking Structure (ETS)	Santa Monica	Enormous covered parking structure, standing-seam PVs	28,172
I	Glenmeade Elementary (ETS)	Chino Hills	Shade structure over outside lunch area for students, standing-seam PVs	10,478
I	University of California Irvine, Engineering Laboratory (ETS)	Irvine	Shade structure over outside lab/storage area, standing-seam PVs	5,241
I	Alamitos Junior High School (ETS)	Garden Grove	Shade structure over outside lunch area for students	10,967
I	Knott's Berry Farm (ETS)	Buena Park	Very large, multiple arrays, roof-mounted	29,719
I	Knott's Berry Farm (ETS)	Buena Park	Small roof-mounted	1,539
I	FAA TRACON	Mt. Davis	Remote microwave relay station, DC powered, pole-mounted, substituted for Chuckwalla site	816
I	FAA TRACON	Whitewater	Remote microwave relay station, DC powered, ground-mounted substituted for McCoy site	816
I	Hotel	San Luis Obispo	Roof-mounted with battery back-up	864
I	Manufacturing Plant	Santa Clarita	Covered parking structure, standing-seam PVs	4,334
III	Office Building	Fountain Valley	Horiz. roof mount, two large inverters	249,930
III	Retail Store	Davis	Horiz. roof mount	8,122
III	Retail Store	Tracy	Horiz. roof mount, string inverters	9,954
III	Auto Body Repair Shop	San Diego	Tilted roof mount	27,227

- **Santa Monica Pier.** This was the largest Phase I installation at about 43 kW. The PV panels were unobtrusive and most would not even be noticed by the average person wandering the pier. There are five large arrays, and only the roller coaster array is visible to the public. All are roof-mounted, three are flat/horizontal, one is mounted at 30° and the other is tilted at 15°. Orientations also vary, although they are all generally southwest-facing. A large dedication ceremony emphasizing the "solar-powered Ferris wheel" was held earlier this year.

- **Santa Monica Civic Auditorium Parking Structure.** This Phase II site is a massive covered parking structure which utilizes standing-seam PV modules. The structure is created from two back-to-back arrays which form a truss. Six 6 kW and one 2.2 kW inverters are mounted at one end of the structure and were humming away producing power during the visit. As this was the only covered parking for miles around, the ETS representative noted that "parking spaces under that carport are the most sought after spaces by the public and city employees".
- **Glenmeade Elementary.** The 10.5 kW standing-seam PV array for this site was integrated into a structure that provided shade to an outdoor eating area for the students where there had previously been none. The school's principal was ecstatic about the structure. She said in addition, the lights that had been mounted on the structure by ETS also allowed them to have functions at night within the outdoor space. For this site, electricity production was a secondary function and in fact, the principal did not seem to know much about it at all.
- **Alamitos Junior High School.** The primary function of this 11 kW system was also to provide shade for an outdoor eating area for the students. This system consisted of two arrays mounted back to back to form a truss-type structure. This site was unusual in that the inverters were mounted high in the air just beneath the apex of the structure. It was also unusual in that this was the only installation with vandalized modules. One of the arrays had 6 broken modules that affected three panels (18 modules). Regarding this problem, the ETS representative mentioned that he had recently made a presentation to the students about the PV system. In talking about the robustness of the system and being able to walk on it without breaking it, he also innocently mentioned that only a brick tossed on top of the system could break it. Within a week of that lecture, someone had vandalized the system by throwing bricks onto it.

FAA Sites

The FAA sites are remote monitoring stations that are grid-tied, but DC driven from a battery pack. PV panels are used to charge and top off the batteries, and therefore do not have the capability to feed electricity back into the grid, only to reduce electricity taken from the grid. These grid-tied systems are almost all located at the end of the utility lines and as such are more subject/prone to outages. Since uninterrupted operation of these systems is critical to flight operations, the PV systems were installed to provide backup energy storage capability.

There are six of these identical systems in the Commission's database. Two systems had received rebates and the remaining four had pending claims. The two that had received rebates were very remote locations close to the California/Arizona border and a four-wheel drive vehicle would have been required for access. Fortunately, since the PV equipment for all the systems was identical, two of the more accessible sites with pending Commission payments were substituted for the two more remote sites. In addition, the FAA contact also provided photos for three of the other sites.

Independent Sites

Photovoltaic systems at independent sites that were verified are described briefly below.

- **Hotel.** This small 900 Watt grid-tied system was installed by its owner as a back-up power system. Apparently, they are subject to power outages during the rainy season. However, the owner did also express some sentiment about environmental concerns being a motivation for installing the system.
- **Manufacturing Plant.** The owner of this 4 kW system is particularly devoted to promoting environmental causes. The covered parking structure with integrated PV panels was constructed not only as a demonstration project reflecting these values, but also as a practical benefit for employees at this manufacturing facility where summer temperatures are often excessive.
- **Office Building.** This large 250 kW system is installed on the roof of an office building and utilizes the horizontal PowerLight module system. The ownership arrangement for this project is unique in that a third-party distributed generation company owns the photovoltaic system that is installed on a building owned and managed by a commercial real estate company.
- **Retail Store.** This 8 kW horizontal system is located on the roof of a hardware store and includes two different types of grid-tied inverters. The systems serve as a sales tool for the store, which is beginning to sell photovoltaic system packages.
- **Retail Store.** The horizontally-mounted PV modules for this 10 kW system are installed several inches above a new, sprayed-on "cool roof". The cool roof consists of several inches of insulating foam designed to reduce air conditioning loads. Five SMA string inverters are located inside the building, and a remote display and project scrapbook are located in a prominent place within the space where customers can monitor the system's output and learn about the technology, the project, and the Emerging Renewables Buydown Program.
- **Auto Body Repair Shop.** This medium-sized system utilizes eleven SMA string inverters and tilted modules. The modules are mounted on racks located on the building's flat roof.

3.2 Performance of Verified Systems

One objective of the verification visits was to assess system performance. Assessment of PV system performance is simplified by using measured data to predict system output under some common reference condition. Treatment in this manner allows direct comparison of system performance levels even if measured data were collected under substantially different solar irradiance or temperature conditions, or if AC data are available for some units while DC data are available for others. Electrical and temperature measurements were taken during verification visits to support the performance assessment analysis.

The common reference conditions selected for this analysis are similar to those developed for use by the Team-Up Program. These conditions, which are commonly referred to as PVUSA Test Conditions (PTC), comprise 1,000 W/m^2, 20 °C ambient temperature, and 1 m/s wind speed. Wind speed data were not collected during verification visits and therefore this element of the PTC was dropped. Data collected during verification visits were used to estimate what system AC performance would have been had reference weather conditions (i.e., 1,000 W/m^2, 20 °C ambient temperature) been encountered in the field.

First, for systems where DC power data were measured, an estimate of AC power output was calculated as the product of DC power output and rebated inverter efficiency. Power output data availability varied between sites. For many of the sites, only DC power output data were collected. Due to access and accuracy reasons, most Trace SW and AEI MultiMode inverters were measured on the DC side, whereas most Omnion, SMA, and Trace SunTie inverters' output level was recorded from the AC power output readout. A local display is not a standard feature on the AEI GC-1000. The AC power output of most of these units, all but two of which were encountered in the third verification phase, was measured using a Fluke 43B power quality analyzer.

Second, adjustments were made for solar irradiance and ambient temperature. The irradiance adjustment consisted of a simple ratio calculation. The temperature adjustment was based on findings of analysis of interval-metered data collected from a sample of residential PV systems (RER 2001). Those findings indicated that a 1 °F increase in ambient temperature typically yielded a 1.14 °F increase in module temperature, and that a 1 °F increase in module temperature typically yielded a 0.2 percent decrease in system power output.

Findings presented in the above referenced report will help put the verification performance assessment results in perspective. That project, which was based on large quantities of hourly interval data collected over many months from a sample of systems, suggests that for 80% of the systems the ratio of estimated PTC system output from field measurements to rebated size was between 70% and 80%. The fact that these ratios presented in the 2001 monitoring study report typically fell between 70% and 80% and never exceeded 87% is not surprising due to a variety of factors, including:

- The rebated size was based on nominal maximum inverter efficiencies. Operating efficiencies under PTC loads and actual operating conditions generally are less. Findings of the monitoring project suggest that a difference equal to approximately

4% is typical. A multiplicative factor equal to 0.96 is therefore indicated for inverter efficiency.

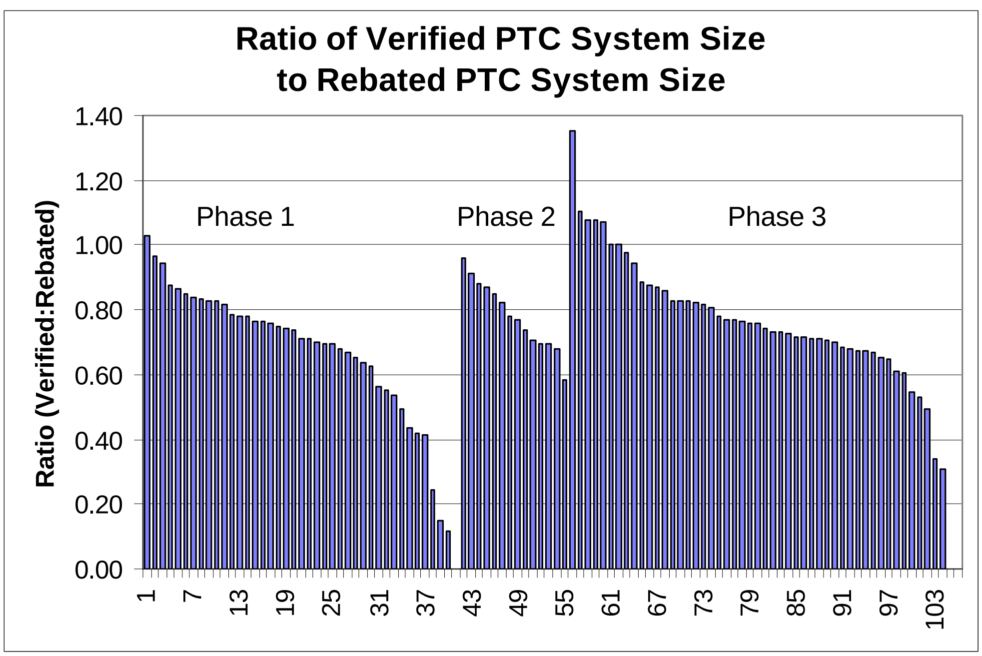
- The calculation of rebated size excludes effects of system wiring, fuses, and disconnects, as well as effects of module mismatch. In other work commissioned by the CEC (Endecon Engineering 2001) a factor equal to 0.95 has been suggested for these factors.
- The calculation of rebated size excludes effects of soiling. In other work commissioned by the CEC (Endecon Engineering 2001) a factor equal to 0.93 has been suggested for this factor.
- The calculation of rebated system size is based on nominal module sizes. Production tolerances may result in actual module sizes being smaller than the nominal value. Researchers in Europe have taken a detailed look at this issue in the past. In other work commissioned by the CEC (Endecon Engineering 2001) a factor equal to 0.95 has been suggested for this factor.

The product of the four multiplicative factors introduced above is 0.8, which is consistent with findings of the monitoring study. Therefore, for the verified systems the fact that ratios of as-built PTC system power output to rebated system size are less than 1 is expected.

Residential System Performance

Most systems were operational and were producing power. Ratios of verification-based PTC system size estimates to rebated size for the verified residential PV systems are summarized in Figure 3-1. The number of points in the graphic is less than the total number of verified

Figure 3-1: Normalized PV System Power Output – Residential Systems



systems because these data were unavailable in certain cases (e.g., low light conditions due to time of day or weather, inverter/wiring inaccessible). As discussed in the previous section, there is some basis to expect actual ratio values in the neighborhood of 0.7 to 0.8. Given the uncertainty inherent in use of spot-measured data to estimate the ratios, a somewhat larger range of 0.6 to 0.9 is a more appropriate target range for purposes of identifying problem systems. With this benchmark in mind, several observations include:

For all three verification phases there are ratio values that exceed 0.9. Results for 14 systems (13 percent) exceed 0.9. It is likely that errors attributable to the data collection methods employed for this project are responsible for these results. While all data collection efforts are subject to an element of uncertainty, several aspects of the verification data collection process may be responsible for the majority of error in these results. The most important aspect relates to coincidence of power and solar irradiance measurements. In most cases instantaneous values were read from the multimeter, and there was a short period of time between the irradiance and power output measurements.

In certain cases measured values displayed on the multimeter were unstable; the instantaneous readings typically used in the analysis do not capture this instability. Principal explanations for power output instability include effects of both maximum power point tracking and clouds, while solar irradiance instability was due primarily to clouds. In all but a few cases there was a short period of time between the irradiance and power output measurements. In cases where cloud cover conditions were changing, or in the early morning or late afternoon when solar irradiance levels were changing rapidly this delay is responsible for introducing an element of error into the analysis.

The primary purpose of the verification was not to develop accurate performance ratio estimates. Rather, it was to identify systems with gross problems suggesting need for more detailed diagnostic and corrective actions. If the emphasis of data collection was on developing accurate estimates of normalized system performance then the data collection procedures could be modified in two principle ways: 1) use multiple meters to eliminate the time gap between collection of power and solar irradiance data, and 2) use averaging feature of meters to measure average value across several maximum power point tracking cycles.

Just as some of the results above 0.9 are thought to be attributable to data collection procedures, so to are some of the results below 0.6. However, some of the results below 0.6 do appear to be associated with system problems. Observations concerning the 19 systems (18 percent) for which a ratio less than 0.6 was estimated are summarized in Table 3-6.

For six systems the cause of apparent poor system performance is not entirely clear, however in two of these cases site conditions required that the solar radiation measurements be taken on the ground instead of in the plane of the array. Reflection effects or sensor tilt/azimuth errors could be responsible for overestimating plane of array solar irradiance, which would lead to underestimating PTC system output. A third system was verified early in the morning; measured plane of array irradiance was 250 W/m^2, but the angle of incidence combined with moderate module soiling could be responsible for low transmittance of incident solar radiation. Follow up data received from the owner of this system suggests that the power output in the middle of the day reaches expected levels. However, the AC current total harmonic distortion (THD) measured at this site exceeded 20%, prompting the inverter manufacturers representative to recommend servicing of the unit. A fourth system was found to be inoperative for no apparent reason. The customer was advised to contact their installer. Finally, one system for which a low performance ratio was estimated during verification was subsequently included in the monitoring study. Interval-metered data collected at this site revealed its performance to be satisfactory.

Table 3-6: Explanations for Low Power Output – Residential PV Systems

Explanation for Low Power Output	n
No apparent explanation	6
Inverter problem suspected (1-Inverter system)	1
Shading during verification visit	3
Inverter problem suspected (2-Inverter system)	5
Inverter not in SELL mode	2
Solar < 100 W/m^2	1
Output limited by battery state of charge	1

Inverter problems and shading were the factors most often identified as being the explanation for low system output. Several customers reported that the inverter initially installed had already failed and been replaced. These early failures were not limited to a single manufacturer. In other cases inverter components required upgrading after installation of the unit.

When there was partial shading on the array, the pyranometer readings were taken in the sunlight, and not in the shade. Developing performance benchmarking ratios for shaded PV systems is problematic. In one case the solar radiation during the site visit was less than 100 W/m^2. The low performance ratio calculated for this system may not accurately reflect performance under full-sun conditions and does not necessarily indicate a performance deficiency.

The incidence of apparent problems with 2-inverter systems was high. In one home, one inverter (of two on the system) had completely failed, and a replacement inverter had already been shipped and was expected to be received shortly following the on-site verification.

At three sites, the inverters were indicating AC output that was erratic and highly variable. One customer reported to the verifier that he had never seen the meter run backwards at the home, even with all the electrical uses at the home shut off. He demonstrated this for the verifier while at the site. These three systems were all two-inverter systems creating a 240 V AC system, which also contained charge controllers and batteries. It appeared potentially that the inverters were "fighting" each other. At a fifth site, the output was very low. After interviewing the customer, it was revealed that they had experienced significant problems with this dual inverter system also.

At another site, the inverter was producing output at a level of about half of what was expected. After significant troubleshooting, testing, and reporting back to the inverter manufacturer by the dealer, the inverter was to be replaced by the manufacturer. What is significant in this case is that this is the <u>second</u> inverter that had to be replaced for this PV system.

Two inverters installed in battery systems were found not to be in *SELL* mode. This is a problem because when the inverter is not in *SELL* mode it cannot send excess power into the utility grid. Instead, PV system power output is constrained by the state of battery charge and by loads on the critical loads subpanel. In these two instances the customer was unaware of this fact, and didn't know there was a problem until the verifier brought it to their attention.

One inverter/battery system utilized an inverter that was not capable of selling power back to the grid. As a result, power output was limited by battery state of charge. This participant reported plans to upgrade to a full-function grid-tied inverter. After the upgrade, system performance is expected to increase substantially.

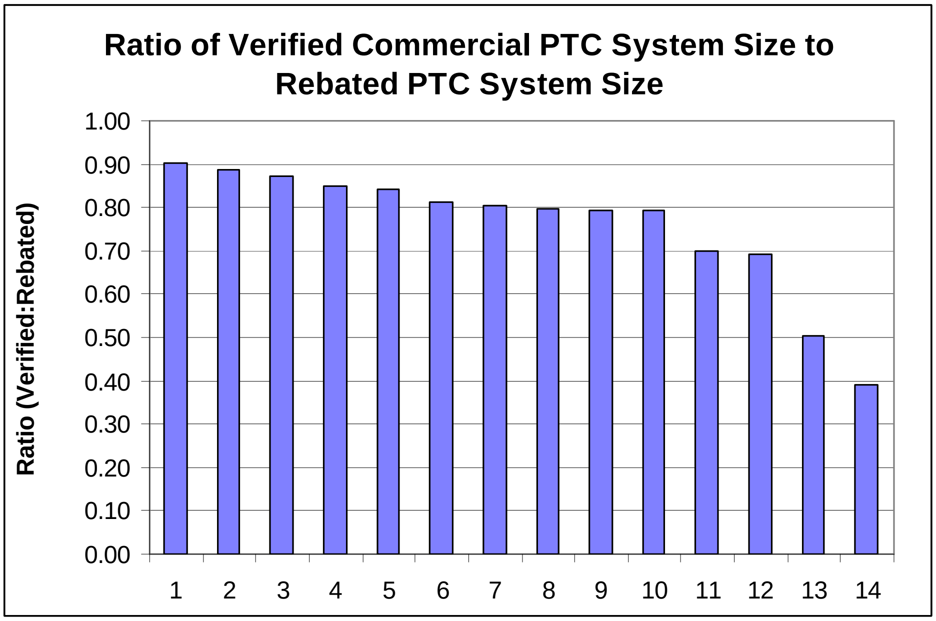
One mechanical/structural issue involved a Zomeworks tracker that failed to "come around" early enough in the morning to direct itself toward the sun before 10 a.m. In that system, the tracker was not picking up the morning sun so there was nearly zero output from the tracker array. At another site one of six 2-axis trackers was not operating due to a failure caused by lighting. There were no other structural/mechanical issues that were apparent.

Performance of wind systems was more difficult to assess. Light, variable wind conditions during the verifications of the small wind systems at seven sites precluded collection of meaningful system output measurements. As described earlier, all of these turbines were subject to turbulence effects of nearby obstructions. The larger wind turbine on the 100 foot tower was observed producing approximately 9.5 kW in a strong, steady wind.

Non-Residential System Performance

Ratios of estimated PTC system size to rebated size for the verified commercial systems are summarized in Figure 3-2. For the non-residential systems there are no instances where the ratio exceeds 0.9, and only 2 instances where the calculated ratios lie below 0.6. One of these systems experienced partial shading during the verification visit, while the other was a small grid-independent battery-based system, the instantaneous output of which is limited by battery state of charge.

Figure 3-2: Normalized PV System Power Output - Commercial Systems



References

Emerging Renewables Buydown Program Photovoltaic and Wind Site Monitoring Results - Phase II Final Report, Regional Economic Research, Inc. for the California Energy Commission, June 2001

A Guide to Photovoltaic (PV) System Design and Installation, Endecon Engineering for the California Energy Commission, June 2001

4

Program Processes and Participant Experiences

4.1 Evaluation of Buydown Program Guidelines Compliance

One important objective of the verification visits was to confirm that hardware makes, models, and quantities observed in the field are in agreement with information in the program files and tracking system. As originally conceived, the verification project was also to include confirmation of receipt and awareness of required warranties. These two aspects of Buydown Program guidelines compliance are discussed below.

Hardware Makes, Models, and Quantities

Maintenance of accurate program records is necessary to ensure rebate magnitudes are appropriate, and to enable program administrators to provide legislators and other interested stakeholders with assurances that program funds are being distributed responsibly. During verification visits hardware makes, models, and quantities were recorded and subsequently compared to information in the program files and program tracking system. No significant deviations between expected and observed hardware were noted in previous verification reports covering Verification Phases I and II. During the third phase of verifications several deviations were observed, as described below.

- In one instance the paperwork and tracking system indicate a combination of 300 Watt and 285 Watt (nominal) modules. These particular ASE-300 modules are unique in that the model number isn't a definitive indication of module size. Rather, it is necessary to infer module size based on voltage and current information appearing on the nameplate. In this particular instance the system was observed to comprise 300 Watt (nominal) modules exclusively. The actual system size is approximately 207 Watts larger than the rebated system size.
- In one instance the paperwork and tracking system indicate a 4,894 Watt system entailing a total of 38 BP5160S modules. The system was observed to comprise 40 BPSX150S modules; the observed system size was 4,824 Watts (70 Watts smaller than expected). In this instance the customer reports not being satisfied with the process whereby the system design was changed without explicit approval or rigorous examination of the implications.
- In one instance the paperwork and tracking system indicate a 199 Watt system entailing a total of 2 Solarex MSX120 PV modules in combination with a 4 kW

inverter. This original design was based on a ratio of rebated system size to inverter size equal to 5%, which is very unorthodox. The system was observed to comprise 8 Kyocera KC120-1 modules in addition to the 2 Solarex MSX120 modules and 4 kW inverter identified in the paperwork. The final cost of this system approached $25/Watt, which appears high given the relatively simple (i.e., flat roof) site conditions. The customer reports not being satisfied with the process whereby the system design evolved.

- For four of the 61 systems verified during Phase III, the observed inverter was different from the inverter expected based on review of program files. In two of these cases a grid-tied Xantrex SunTie 2500 inverter was replaced with an SMA SunnyBoy 2500 inverter due to performance/availability concerns with the Xantrex unit. In at least one of these cases the SunTie unit was installed for a short period of time before being replaced. In a third case a stand-alone inverter was replaced with a unit of the same size and from the same manufacturer that was capable of grid-interactive operation. Finally, in one case a Xantrex SW 5548 was expected while two Xantrex SunTie 2500 inverters were observed. This final case represents a system that is routinely reconfigured for testing purposes. In none of these four cases where inverters were not in agreement with program records were the program participants dissatisfied with the exchange, and the impacts on system sizes were small.

There are important relationships between the verification scheduling process and development of information necessary to draw general conclusions concerning the accuracy of program records and the validity of participant rebate claims. If large numbers of participants objected to verification visits then one might suspect that actual system configurations differed from those represented on application and claim paperwork by program participants and system retailers/installers. Throughout the three phases of verification visits there were no occasions when this was suspected. There were instances where verification visits could not be scheduled due to vacation and other schedule conflicts, but in these instances program participants generally offered to allow cursory, unattended inspection, or suggested another date/time more convenient for their schedule.

Warranties

During the Phase I verification visits system owners were asked to present warranties required for program participation. Overall, 32 of the Phase I verification subjects did not remember having seen or received one. In talking with some of the dealers/installers of these systems, it was clear that during the initial days of the program there was not universal understanding among dealers as to detailed requirements of the five-year warranty. Subsequent to these initial verification visits program implementers consistently maintained warranty compliance information in program files. At this point in time the value yielded by double-checking warranty paperwork in the field became low and this aspect of verification activity was dropped from verification Phases II and III.

4.2 Feedback concerning participant experiences

Summary of Buyer Comments

Program participants were asked a series of face-to-face interview questions by the verifier while he was at the site. The questions were not asked in "survey language," as a statistically valid survey might, but conversationally. The verifiers asked these Emerging Buydown Program end-users about 1) the customer's motivation for buying a PV system, 2) what their experience of buying/installing was like, including their impressions of the utility, the dealer/installer, building officials, and Commission, and finally 3) if they had comments they would like to make to "the world", the Commission, or other stakeholders.

Discussion and Analysis

The participants were very frank and open with their comments. It was clear that these customers were intelligent, concerned, knowledgeable, and committed to solving their own issues with PV. These residential homeowners can mostly be described by "early adopter" profiles. For many, however, the purchase of the PV system was a practical solution to make sure that their lifestyle would continue uncompromised despite (sometimes frequent) distribution system power outages in their area. During the third phase of verifications substantial numbers of participants began citing concerns over the cost of traditional utility power as a motivation for system installation.

The buildings (homes) for which the PV systems were installed ranged from very modest (less than 1,000 ft^2 in a relatively low-income neighborhood) to large (3000 ft^2 plus). While financing was not an issue discussed with participants, it appeared that most, if not all, these participants paid cash for their systems.

Motivation for Buying Systems

Much of the motivation behind buying systems was related to improving the reliability of electricity supply. Many of the Phase I homes are located far from substations and on the "end" of radial distribution circuits. Many customers included in subsequent verification phases experienced electric supply disruptions as a consequence of recent disruptions in markets for electricity in California. The customers' self-reported motivation to improve power reliability is clearly demonstrated by the fact that 78 of the 117 residential systems (67 percent) verified had battery storage back-up capability. The proportion of residential participants installing systems with batteries stayed relatively constant across the three verification phases. A much smaller percentage of non-residential systems included batteries (3 of 15, or 20 percent).

A second major self-reported motivation was environmental consciousness. Several wanted to "make a better world" for their children/grandchildren. Some of the environmental motivation was mitigation-oriented: one family bought the system to counteract the pollution that will be caused by their substantial commuting in their new vehicle. Several (9) of these motivated homeowners either had a solar water heating system already, had an earlier PV or solar water heating system, or had a solar heated home. Concern for the environment was the reason for installation most often cited by participants whose systems were verified during Phase III.

A third motivation was the philosophical appeal of distributed, self-generation versus dependency on a large, monopolistic electric utility. This motivation was most apparent, as many participants loved to show the verifiers their meter running backwards, which was a fulfilling experience for many.

A fourth self-reported motivation was to ameliorate any "Y2K" problems with power. This motivation was mentioned by eight of the owners verified during Phases I and II. In one case the customer felt very strongly that Y2K was going to be a significant long-term problem for utilities and other public-service suppliers, so they elected to include PV among numerous Y2K preparedness systems. Y2K concerns continued to be cited by owners of systems verified during Phase III. Ten such owners cited Y2K concerns; however, all ten of these were owners of systems verified during 2001. No such reports were noted during the Phase III verification visits completed during 2002. This result is expected, as none of these systems was completed prior to 2001. None of the non-residential system owners cited Y2K concerns as a reason for system installation.

A fifth motivation is from those planning on "going into the business" or are already in the business of selling/installing solar PV systems. Six PV homeowners saw this as the key to getting further experience and having a demonstration site for their business' products and skills. A seventh homeowner is an educator in energy efficiency felt it was important to get real-life experience with a system. Two additional Phase III system owners revealed plans to enter the PV supply business. One is a general contractor with a longstanding interest in solar energy. A second participant is a small business owner whose disappointing experience with existing PV installers led him to install his own system and start a solar business.

A sixth motivation was as a creative project for the hobbyist/do-it-yourselfer. Although this motivation is most apparent for the do-it-yourself (DIY) installations it is also suspected as a secondary motive for others as well.

During the third phase of verifications, increasing numbers of program participants began to cite "concerns over the cost of utility power" as a reason for system installation. During Phase I, only 3 of 56 (5%) mentioned this factor, as compared to 15 of 26 (58%) of those verified during the summer of 2002. One of these customers reported being 'dismayed' that their inverter lacked even a basic display of performance. Another reported being very disappointed with system output. The performance ratio of the latter customer's system was estimated equal to 0.7 during the verification visit, which is typical of values estimated for other systems. This customer reports that if he knew then what he knows now about PV system performance and cost he wouldn't have installed the system.

Another motivation appears to be personal recognition and increasing public awareness about solar. This is difficult, however, because there are no bells or whistles associated with the PV systems. The solid-state systems operate without any moving parts, so the only mechanical/visual indication that these systems are operating is the electric meter running backwards, which is not that impressive to the typical person. Many expressed the frustration of this feature and indicated that this is one of the challenges with increasing the "show-and-tell-ability" of PV systems. Being able to "talk about your system" or "bragging rights" as one homeowner put it, is impossible without knowing how well it is doing.

Interaction with Other Stakeholders

Utility Technical/Interconnection Issues. Only a couple of homeowners reported that they had experienced technical interconnection issues with the utility. The dealer/installers seem to have insulated the owners from any dealings with the utility on technical issues. Several homeowners did complain about (after repeated contacts) being unable to get the PG&E technical crew out to inspect their systems and approve them for interconnection in a timely manner. Also, because they were barred from interconnecting until after this inspection/test, it held up their "running the meter backwards." Another customer, the first to install a system in SDG&E territory, had numerous problems requiring multiple Commission interventions. However, the final result was positive and at the end of the process the utility thanked the customer for helping them get up to speed.

In Phase II verifications, several of the sites in PG&E service territory did not have utility accessible, lockable disconnect switches. This configuration was typical of one installer working in a specific PG&E local area. The requirement (or rule interpretation) for this switch seems to vary across local PG&E offices.

Utility Administration and Billing. By far, the largest area of complaint from the PG&E customers whose systems were verified during Phases I and II was the length of time that it took/is taking PG&E to get their billing and accounting information correct. Several reported that they get large volumes of multiple "bills" each month. At least one customer gets a "commercial" bill (rather than residential), another participant reported that it had been months since they had received a bill, yet they were sent a notice of disconnect if they did not pay. All of these customers have been working with PG&E, some for many months, to resolve and straighten out their billing. In one case, the customer had been communicating with PG&E for months to get on the correct billing for a PV system. Only when the meter reading started reading negative in an early summer month, did the local office finally determine the correct rate schedule. Another customer cited that they felt that PG&E was just not coordinating internally with each other – one side (technical) is doing something, but the other side (Administrative/Billing) did not.

During Phase III verification visits twenty-five residential system owners provided feedback on their experience with their utility. Twenty-two of these systems were in the PG&E service territory. Fifteen reported having had a smooth experience with the utility while 10 reported having had a bad experience. Complaints reported during Phase III verification visits were similar to those noted during verification Phases I and II. Dissatisfied customers reported having had problems with inadequate explanations of complicated bills, and with rate switching delays; three customers reported that the utility "...never returned their calls...". Five of the ten customers dissatisfied with their utility installed their system themselves; the other five systems were installed by a contractor.

Similar problems were reported by SCE and SDG&E residential customers, but problems do not appear to be quite as extensive as they are for PG&E customers.

Local Code/Building Officials. Most customers did not have direct interaction with the local code officials, so had few if any comments concerning this aspect of their system's installation. The majority of those participants who did provide feedback on their experience with local code/building officials reported that they were disappointed by the level of expertise and familiarity with small grid-connected renewable energy systems displayed by those responsible for permitting and inspecting their system. Of the sixteen participants offering feedback in this area, only one reported being very satisfied with their local code/building officials. In this isolated case the building official was interested in photovoltaic technology and so took a special interest in the project. However, in the rest of the cases participant feedback indicated some level of dissatisfaction with the permitting or inspection process. A variety of reasons for the dissatisfaction were offered, all of which were related either to the level of expertise/familiarity with the technology displayed by the code/building officials, to the length of time required to complete the process, or to the cost involved with completing the process.

Dealer and/or Manufacturer. Almost all homeowners reported excellent relationships with their equipment suppliers, dealer, and installer. Many had highly complimentary statements about how the dealer "took care of everything" and they had little to be concerned about.

One Phase I customer was significantly dissatisfied, however, with her dealer because he did not tell her that the output of the PV system will decrease as the (ambient and cell) temperature rises. She had been experiencing low output as the seasons became warmer – and would have bought a larger system if she had known of this operating characteristic of PV systems. Another customer felt that the dealer had provided inadequate explanations about system operation and troubleshooting, and would not answer the customer's questions in a timely manner.

Several customers were very upset about their dealings with Trace Engineering, a manufacturer of power inverter systems. In the cases of two systems that are both significantly under performing, the customers reported significant lack of responsiveness from the company to receive troubleshooting assistance. Trace personnel were extremely difficult to get a hold of, and were of limited help in many cases. In both cases, the customer was very pleased with their dealer/installer/supplier, and how they were taking significant steps to communicate with Trace. Several Phase III participants reported having problems with the new Advanced Energy MultiMode inverter. Three such inverters were reported to have burned out, necessitating replacement.

Customer feedback gathered during Phase III verification visits included substantial numbers of reports of both very good experiences with dealers as well as rather poor experiences. Again, only a few of the sites were selected because of ambiguous or inconsistent paperwork or customer complaints. Twenty-four of the customers had positive things to say about the performance of their retailer/installer, while twenty-one had negative things to say. Complaints covered a broad range, including: poor customer service, poor communication, poor instructions, excessive price, underperformance, improper wire sizing, poor attention to detail, and lack of expertise. Two participants cited the need for better system rating information; two others suggested that all systems should be required to include some provisions for local performance monitoring.

Participant Comments on California Energy Commission & Buydown Program

Reactions to the Commission regarding the program were almost all supportive. Some customers, however, had recommendations and questions related to program administration and improvement. Many customers reported that the Commission program was the catalyst that they needed to turn a long-term aspiration into reality. Several participants said explicitly that if it were not for the program, they would not have installed the system for which they received a buydown incentive. One customer thanked the Commission specifically for "going to bat for him", helping make headway with a utility that was going to charge a large fee for a new meter to be installed.

The most common criticism of program administration concerned taxability of buydown incentives. Six participants stated that they were upset (from mildly upset to very angry) that the buydown incentive was taxable, and that the Commission did not make this point clear enough on program forms and promotional materials. Other reports of disatisfaction with program administration during Phase I verifications in 1999 concerned isolated incidents involving recalculation of a buydown incentive magnitude, and a claim of slow payment of a buydown incentive. Review of program records reveals that the incentive recalculation was required to correct faulty information provided initially by the participant, and the payment of the latter incentive was made in a considerably shorter time period than the customer recalled. Finally, several Phase III customers reported problems with slow turnaround and lost paperwork.

Effectiveness of Buydown Program (from Verification Findings)

As mentioned before, the Buydown program was the catalyst that caused many of these participants to buy a PV system. This is not to say that it caused them to start thinking about PV – most had been thinking about purchasing a PV system for awhile, and this established the timeline for purchase. The Buydown program was not as effective, at least to the Phase I participants, in creating new interest among customers who had not considered PV before. The Buydown appears to be an effective tool as used by the contractors, however, in making a sale.

From several Phase II and Phase III interviews, participants especially wanted to tell the CEC that they should do a lot more marketing and advertising to promote the Emerging Buydown Program. These participants were particularly committed to the environment, and felt that the program *was not publicly promoted enough* through media and other means.

Problems/Issues with Buydown Program

Based on the findings of the verification task, there did not appear to be significant flaws in the Buydown program as it is currently being run. Because of the limited scope of the verification task, and the fact that most end-use customers are insulated from direct contact with the Program, more information about any problems or issues would come out in the dealer/installer surveys. In most cases, the dealer/installers had the direct contact with the Buydown Program.

One concern, however, with the Buydown Reservation procedure, was observed on some Phase I verifications (1999). A comparison of the rebates paid based on data entered on the participant's Reservation Request Form versus what should have been paid based on data gathered from the verification site visits showed some inconsistencies in installed watts and rebate calculation methods. For instance, some customers used module wattages and inverter efficiency ratings that were not consistent with those values presented on the Commission's certified equipment listings.[1] Others rounded to the nearest 1, while still others took calculations out to the nearest decimal. Although the differences were usually minimal as a percent of the total rebate paid, they do seem to indicate that data submitted on the Reservation Request Form is not being checked against the Commission's certified equipment list. The net effect of this is that the Commission actually paid out less in rebates than they would have if Commission certified module wattages and inverter efficiency ratings had been used.

There were specific requests for program changes from individual participants and dealers that the verifiers interviewed. While these are not specifically endorsed (or may not even be legal), they are provided for Commission's consideration to fulfill the interviewees wishes that these be passed on:

1. Issue lists of UL-listed PV equipment,
2. Consider giving rebate based on dollars per annual kWh expected to be generated, rather than dollars per peak kW, and
3. Consider expanding program to municipal utilities.

[1] Certified Photovoltaic Modules http://www.energy.ca.gov/greengrid/certified_pv_modules.html
Certified Inverters http://www.energy.ca.gov/greengrid/certified_inverters.html

5

Evaluation of RER’s Site Verification Operations

There are many aspects of the Verification task that went well, and others that needed improvement along the way. The verification appointments for one week (12-17 buildings) could be made in two evenings of telephone calls (4 –5 hours) plus some stragglers. Commercial customers were called during normal business hours successfully. Residential participants were available after work hours and most calls were made from 4 to 7 p.m. Other calls for residential verifications were made during business hours, and there was usually someone home who could provide a business telephone number to call. They were all welcoming of the verifiers, except a few needed to have more time getting comfortable with the explanation of the verifications. Most appeared to be glad to talk about and “show off their systems” to someone who knew something about them. A few requested advice/information from the verifier as a knowledgeable third party.

Customers were generally available for appointments at times that were convenient from a scheduling standpoint. The approach to schedule appointments for a week in a pre-set “circular” geographical path, beginning and ending at a focal point (airport or home) with minimum of backtracking, was very successful in saving time and gasoline.

The verifications were mostly accomplished in the allotted time. A verification visit with no complications (most did not have complications) could be done in less than an hour, including taking all measurements. Unknown time factors involved the discussion of concerns or questions of homeowner, equipment technical problems, or additional time required to conduct the interview.

There are also some concerns about the Verification task, as planned and implemented by RER. First, after the Phase I verification visits were completed it was clear that there was no real need to check for building permits or warranties because they had already sent them in to the Commission. Most participants at the field visit said it was in their file or office and was not readily accessible. Assessment of these program elements could be completed more effectively in the context of a program process evaluation. Because of this fact, during later verification phase’s customers were not asked to provide copies of permits or warranties.

Second, it takes time between visits for travel, and in many cases it is necessary to allow for at least two hours for each visit (including travel) to assure punctuality, which is critical when dealing with customer/participants. Ninety minutes may be enough of a spread for systems in close proximity. In some cases there was uncertainty as to how long it would take to drive between sites due to uncertain traffic congestion and road conditions. Weather conditions and length of day are important considerations, too, when scheduling appointments, especially in late fall or winter.

5.1 Budget Implications

The inability to schedule appointments literally "back to back" resulted in the verifiers spending time on the road not being used strictly in verifying systems. Nevertheless, this interim time was spent checking locations, taking further site notes, checking equipment, entering data, etc. It is important to avoid scheduling appointments too close together in order to assure punctuality and customer convenience for each customer.

The Phase I verification sites were located further apart than those verified during Phase III. During Phase I, in certain cases it was possible to perform up to 15 sites per week (3 per day) instead of the planned two per day. This reflected in less time spent on travel expenses and verifier labor. Due to the much larger pool to sample from the Phase III sites visited on particular days were located closer together, thereby allowing completion of 4 sites per day (or even 5, in the case of a wind system that it was possible to verify in lower light conditions). The cost drivers of the verification task were the actual driving time and the time required in-between appointments. The verification appointments themselves were actually very efficient.

5.2 Timeline Implications

Generally speaking, the verification process for Phase I took less time than was planned. In the original estimate, it was anticipated that two verifications could be done per day. As it resulted, three verifications per day were practical and easily doable. Because of this, the PG&E territory sites (38 in Phase I, 15 in Phase II) were covered in 21 working days respectively, rather than the 26 days planned. The three-site-per-day goal was missed only because there were not enough verification sites in a particular area. To illustrate the downward trend in verification visit time requirements associated with the increased population of systems from which to sample, the final 17 verifications completed in the PG&E service territory were completed in 4 working days.

Time Required for Verification at Each Site

The actual time required for each site verification *at the site* ranged between 50 minutes and 1½ hours. Time at the site was mostly dependent on a) how much the owner/participant wanted to be involved in the verification process, b) whether or not the customer was experiencing technical problems with the system that would cause him to request checks on various things, c) how much the customer wanted to discuss their system, and d) difficulty in reaching system components for verification. Technical time issues depended on the necessity to remove any covers from equipment to measure wattages, but this did not require much time at all.

5.3 Scope & Protocol Implications

Based on experience with the three phases of verification visits, several observations and recommendations related to scope are indicated, as summarized below:

- Eliminate need to see/record building permit and warranty – Program participants are required to provide a copy of these documents as a condition of receiving a rebate. Oftentimes these documents are not able to be quickly located in the field. Time in the field would be better spent by focusing on collecting information that can be collected only while in the field (e.g., power output).
- Use an infrared thermometer to collect module temperatures. Some of the variability observed in performance ratio estimates is attributable to the fact that module temperatures at PTC conditions will vary depending on a variety of factors. Switching from ambient temperature to module temperature normalizing would minimize the influence of configuration effects and make it easier to isolate problems associated with hardware/setup problems.
- Use two averaging meters to collect solar irradiance and power output data. This would substantially decrease measurement error introduced by factors such as variable cloud cover and maximum power point tracking. Measurement errors could be further reduced by consistent use of a power quality analyzer to measure true power on the AC side of the inverter.
- Add the requirement to measure instantaneous inverter efficiencies by measuring both DC power input and AC output. Although only one data point subject to important measurement uncertainty constraints, this could provide useful information for checking the system.
- Add the requirement to record the presence and model of charge controllers and the size of the battery bank (kWh or Ah).
- Require measurement and recording of the DC voltage at the input to the inverter and/or charge controller.
- Collect the system installation and start up dates, cumulative energy output, and any noted system down times during that period. This could provide useful data about actual power production and system reliability.

- Use Email to set up verification appointments – In the few cases where the customer's Email was available, this was an ideal communication path to set up appointments with busy people.
- Use Yahoo maps (http://maps.yahoo.com/py/maps.py) to estimate driving times and distances.

6

Conclusions and Recommendations

To date, three rounds of verifications have been completed. A total of 132 sites were visited from May 1999 through June 2002. Several conclusions and recommendations are indicated by this experience, as described below.

6.1 Conclusions

Conclusions resulting from the three phases of on-site verification visits are summarized below:

Program Guidelines Compliance

- To date, there has been very close agreement between hardware observed in the field and hardware descriptions indicated in Program documentation and the program tracking system. The few exceptions appeared to represent modifications of convenience as opposed to attempts to use deception to collect rebate funds. The incidence of these exceptions appears to be increasing as program activity increases, however.

System Performance

- Information necessary to establish realistic system performance expectations and to assess actual performance is lacking. The weather-sensitive nature of system performance contributes to the difficulty of translating component nominal rated performance information into realistic estimates of system performance. Lack of reliable system performance data increases the risk that program participants will be disappointed with the actual output of their system. Many participants' PV systems have no means to indicate how much energy their PV system is supplying so they cannot determine whether or not their system is working properly (or at all).
- Inverter reliability and performance have considerable room for improvement. Operating performance of two-inverter systems with batteries was particularly problematic, although the incidence of problems with battery less maximum power point tracking systems is also an area of concern. Reports of inverters being 'dead on arrival' or failing shortly after installation continue to be received.
- The siting of small wind systems less than 1 kW tends to depart significantly from standard rules of thumb. Short towers (< 50 feet) located in close proximity to

turbulence-causing obstructions were the norm rather than the exception for the verified systems. The actual energy output of these systems may be significantly less than estimates based on more ideal conditions.

Participant Feedback

- While reliability and environmental considerations continue to represent important motivating factors for system installations, concerns over the cost of electricity from traditional sources is an increasingly important factor. These customers are likely to be particularly concerned about actual system performance relative to expected performance.
- Utility relations are an important area of concern for program participants who report difficulty completing the interconnection process, transitioning to new rates, and obtaining information from utility representatives. Program participants were particularly concerned about phone messages to PG&E not being returned.
- The level of familiarity of local permitting and inspection staff with small, renewable distributed electric generation systems is generally minimal. Program participants routinely report that the individual performing the inspection “didn’t know what they were looking at”.
- Participants are generally very happy with the Buydown program and would like to see it promoted more aggressively. With only rare exception, program participants report that they would not have installed a PV or wind system in the absence of financial support from the Buydown program. The lone area of dissatisfaction concerns the issue of incentive taxability. Participants who learned of the taxability when they received notice from the IRS reported being upset, in at least one case to the point of being ‘very angry’. The incidence of dissatisfaction related to this issue appears to be increasing.

6.2 Recommendations

There are several principal recommendations that can be made to the Buydown Program’s implementers based on findings of this multi-year verification task:

- The Commission should continue its program of on-site verification visits. These visits provide information necessary to provide assurances that program funds are being spent responsibly. During the third phase of verifications several minor discrepancies between actual and claimed system details were observed. An on-going, limited program of on-site verification visits is an effective strategy for monitoring, and ultimately resolving, these problems.

  On-going verification visits can also help the Commission keep apprised of performance advances or problems associated with new installers/dealers and new hardware makes/models. The performance and safety of owner-installed systems has been a concern of the Commission. To date, this sector has demonstrated considerable proficiency where system installation and operation are concerned. There is no guarantee that this will remain the case if markets for PV and wind systems expand into groups with different levels of technical expertise and experience.

To increase the probability that systems with performance or installation problems are included in future phases of on-site verification visits the Commission could conduct screening telephone surveys of program participants. Telephone interviews would include questions regarding the customer's PV system, its performance, and the customer's interactions with other stakeholders. Based on results of the screening calls a sample of participants with completed systems would be selected for on-site verification visits.

- The Commission should increase the visibility/clarity of information and disclosures related to the possible taxability of rebates. The Consumer's Guide to Buying a Photovoltaic System identifies potential tax benefits of using a mortgage to finance a PV system and it includes a relatively detailed financial analysis for a hypothetical PV system, but it doesn't mention the potential impacts of income taxes on net system costs. This issue of rebate taxability is alluded to on page 2 of the Program Guidebook:

  > "Customers participating in the Buydown Program may wish to consider the possibility of designating the retailer as the payee in order to mitigate potential income tax implications."

  The continued incidence of complaints about rebate taxability suggest that this message should be made more clear and more prominent. The message could be made more prominent by including it on the Reservation Request Form. Space on this form is limited and maintaining its simplicity is important. However, the incidence and intensity of complaints about this issue suggest that the Commission should consider modifying the Reservation Request Form. The modification might entail adding "This designation may have important tax implications. See Program Guidebook for more information." to the Payee Designation box on the Reservation Request Form. The clarity of the message about potential taxability could be increased by adding some additional description of the issues and options to the Program Guidebook.

- The Commission should develop and/or disseminate information related to siting and performance of small wind systems. The Commission's recently released Guide to Buying a Small Wind System suggests that "If you think you have a good wind resource, you probably do." Findings of the verification visits as well as the monitoring study suggest that this may not necessarily be the case. There would be great benefit in collecting actual energy production information from a sample of small wind systems and making this information available to prospective program participants.

- The Commission should develop and/or disseminate information related to actual performance of PV systems. It is not uncommon for program participants to report that the actual output of their system is lower than they expected. These expectations may be influenced in part by rebated system sizes developed on the Reservation Request Form. Findings from the monitoring study or elsewhere should be used to develop information relating rebated size to actual expected system power output. This information could be added to the Consumer's Guide, or presented in a short document posted on the Commission's web site. Ideally, this material would include information necessary for participants to monitor system performance and identify problems that may crop up in the future.
- The Commission should require some type of local/easy access performance indicator (preferably kWh) for each system approved under the Program. Participants often do not know when or how well their systems are working, or under what conditions they should call their installer for service. In off-grid homes (the majority of PV systems sold prior to the program), indicators of battery state-of-charge (or simply loads starting to disconnect!) may be all that is necessary for the customer to know if his system is working. Grid-tied customers always have power available from the grid, but still need to know/understand: a) if the PV system is working; b) if the system is providing an amount of power consistent with environmental conditions, and c) how much energy the system is providing on a daily, monthly, and/or annual basis. The GPU UPS monitor was included as an option on some verified systems, and this provided the information descussed in items a) and c) above. Some recently introduced batteryless inverters also provide these data. Part b) might be fulfilled simply by a handout sheet containing information summarizing the temperature sensitivity of PV system output and the variability of clear-sky solar irradiance as a function of month and time of day.
- The Commission should continue its programs of training for local permitting staff, inspectors, installers, and customers.

Appendix A

Listing of Phase I, II & III Verification Sites

APPENDIX A: Site Verification Information

Reservation ID Number	Location	Market Segment	Technology	Size (Watts)
Phase I:				
1	Concord, CA	Residential	PV	1923
2	Walnut Creek, CA	Residential	PV	1976
3	Moss Beach, CA	Residential	PV	1943
11	Westlake Village, CA	Residential	PV	2949
12	Culver City, CA	Residential	PV	1945
17	Paradise, CA	Residential	PV	1230
18	Nevada City, CA	Residential	PV	1542
20	Grass Valley, CA	Residential	PV	2466
21	Auburn, CA	Residential	PV	1016
22	Saugus, CA	Residential	PV	5017
25	Irvine, CA	Commercial	PV	5241
26	Chino Hills, CA	Commercial	PV	10,478
27	Garden Grove, CA	Commercial	PV	10,967
28	Santa Monica, CA	Commercial	PV	42,456
30	Santa Clarita, CA	Commercial	PV	4334
38	Grass Valley, CA	Residential	PV	3928
39	San Francisco, CA	Residential	PV	1902
42	Sunnyvale, CA	Residential	PV	1970
44	San Luis Obispo, CA	Commercial	PV	864
47	Cupertino, CA	Residential	PV	1502
48	Orinda, CA	Residential	PV	775
49	Menlo Park, CA	Residential	PV	1970
63	Santa Cruz, CA	Residential	PV	1970
64	Santa Ana, CA	Residential	PV	3067
65	Berkeley, CA	Residential	PV	2846
67	San Jose, CA	Residential	PV	1970
69	Marin County, CA	Residential	PV	3940
70	Tehachapi, CA	Residential	PV	2095
71	San Francisco, CA	Residential	PV	262
73	Buena Park, CA	Commercial	PV	29,719
76	Belmont, CA	Residential	PV	3940
81	San Francisco, CA	Residential	PV	1803
102	Berkeley, CA	Residential	PV	1803
107	Brentwood, CA	Residential	PV	3384
110	Mendocino, CA	Residential	PV	777
129	Auburn, CA	Residential	PV	830
134	Half Moon Bay, CA	Residential	PV	3940
135	San Diego, CA	Commercial	PV	816
136	San Diego, CA	Commercial	PV	816

Reservation ID Number	Location	Market Segment	Technology	Size (Watts)
Phase I:	(Continued)			
150	Warner Springs, CA	Residential	PV	1539
159	San Luis Obpiso, CA	Residential	PV	2365
160	Paso Robles, CA	Residential	PV	3452
161	Wildomar, CA	Residential	PV	1282
162	Oakland, CA	Residential	PV	1910
165	Mill Valley, CA	Residential	PV	1352
166	Grass Valley, CA	Residential	PV	511
168	Santa Cruz, CA	Residential	PV	1970
170	Brentwood, CA	Residential	PV	385
186	Hollister, CA	Residential	PV	1803
191	Nevada City, CA	Residential	PV	1044
195	Nipomo, CA	Residential	PV	1777
199	Fremont, CA	Residential	PV	3948
203	Fairfield, CA	Residential	PV	1781
231	Napa, CA	Residential	PV	1524
232	Arroyo Grande, CA	Residential	PV	1626
PHASE II:		**Phase I**	**Average Size:**	**3,526**
206	Soquel, CA	Residential	PV	6728
217	Oakland, CA	Residential	PV	2426
221	Ben Lomond, CA	Residential	PV	3659
230	Cupertino, CA	Residential	PV	2566
233	San Francisco, CA	Residential	PV	2924
245	Mariposa, CA	Residential	PV	1644
250	Oakland, CA	Residential	PV	1941
265	Boulder Creek, CA	Residential	PV	2033
274	Los Altos Hills, CA	Residential	PV	1910
305	Soquel, CA	Residential	PV	1184
329	Mountain Ranch, CA	Residential	PV	691
379	Hayward, CA	Residential	PV	1995
388	Clovis, CA	Residential	PV	3247
398	Mariposa, CA	Residential	PV	805
409	Mountain View, CA	Residential	PV	1367
		Phase II	**Average Size:**	**2,195**

Reservation ID Number	Location	Market Segment	Technology	Size (Watts)
Phase III:				
238	Berkeley, CA	Residential	PV	2,071
259	Nevada City, CA	Residential	PV	2,054
278	Grass Valley, CA	Residential	PV	1,306
328	Mountain Ranch, CA	Residential	PV	790
371	Los Gatos, CA	Residential	PV	3,287
417	Berkeley, CA	Residential	PV	805
440	Grass Valley, CA	Residential	PV	1,192
444	Auburn, CA	Residential	WIND	1,920
445			PV	2,793
452	Los Gatos, CA	Residential	WIND	376
453			PV	1,690
466	Berkeley, CA	Residential	PV	2,992
479	Woodacre, CA	Residential	PV	893
489	Tiburon, CA	Residential	PV	1,941
491	El Cajon, CA	Residential	PV	911
749			WIND	444
496	Berkeley, CA	Residential	PV	782
506	Camino, CA	Residential	PV	805
615	Oakland, CA	Residential	PV	1,220
635	Mill Valley, CA	Residential	PV	893
669	Long Beach, CA	Residential	PV	3,450
689	Penn Valley, CA	Residential	PV	2,073
717	Oregon House, CA	Residential	PV	845
726	San Jose, CA	Residential	PV	1,142
727			WIND	887
752	Petaluma, CA	Residential	PV	3,229
778	San Jose, CA	Residential	PV	5,263
801	San Diego, CA	Residential	PV	728
816	Fountain Valley, CA	Commercial	PV	126,276
821			PV	123,654
830	Costa Mesa, CA	Residential	PV	1,820
832	Vista, CA	Residential	PV	7,895
833	Granite Bay, CA	Residential	PV	2,009
862	La Mirada, CA	Residential	PV	2,385
874	Jamul, CA	Residential	PV	1,775
883	Capistrano Beach, CA	Residential	PV	1,609
911	Agoura Hills, CA	Residential	PV	4,109
1316	San Diego, CA	Residential	PV	3,832
1363	Tracy, CA	Residential	WIND	9,500
1471	Tracy, CA	Residential	PV	4,027
2562			WIND	1,812

Reservation ID Number	Location	Market Segment	Technology	Size (Watts)
Phase III:	(Continued)			
1565	Poway, CA	Residential	PV	9,538
1644	Poway, CA	Residential	PV	2,385
1654 1655	Loomis, CA	Residential	WIND PV	1,812 4,772
2066	Camarillo, CA	Residential	PV	2,008
2128	Stockton, CA	Residential	PV	9,439
2134	San Diego, CA	Residential	PV	2,962
2182	Cupertino, CA	Residential	PV	2,009
2197	Simi Valley, CA	Residential	PV	9,893
2271	Mountain View, CA	Residential	PV	1,966
2308	Pilot Hill, CA	Residential	PV	9,538
2390	Auburn, CA	Residential	PV	3,974
2396	Redwood City, CA	Residential	PV	3,040
2768	Santa Clarita, CA	Residential	PV	3,414
2941	Placerville, CA	Residential	PV	9,428
3092	Poway, CA	Commercial	PV	27,227
3310	Bakersfield, CA	Residential	PV	199
3333	Davis, CA	Residential	PV	3,466
3641	Davis, CA	Residential	PV	2,175
3801	Bakersfield, CA	Residential	PV	4,740
3885	Cupertino, CA	Residential	PV	3,926
4293	Davis, CA	Residential	PV	1,004
4500	Tracy, CA	Commercial	PV	9,954
4582	Davis, CA	Commercial	PV	8,122
4661	Canyon Country, CA	Residential	PV	8,243
4697	Stockton, CA	Residential	PV	830
5167	Camarillo, CA	Residential	PV	5,054
		Phase III	**Average Size:**	**7,185**

Appendix B

Copy of Blank Field Verification Form

Emerging Buydown Program
Renewable Energy System On-Site Verification Checklist

Customer Name:		Date of Verification:	
Address:		Start time:	
Reservation Number:		Time of Verification:	
Utility:			

Type of Renewable Energy System: PV Wind Fuel Cell

Part 1: Determine if system installed consistent with Reservation

I. Photovoltaic System

1. Brand/Model Number of Photovoltaic Modules:			
2. Modules CEC Certified/Same as in Reservation?			Y/N
3. Number of modules:			
4. Wattage of each module (PTC):			Watts
5. Installed wattage:			Watts
6. Inverter/Charge Controller Brand/Model:			
7. Inverter CEC Certified/Same as in Reservation?			Y/N
8. Inverter Efficiency (CEC)			%
9. Total derated Output of System = (3) x (4) x (8)		0	Watts
10. Total calculated incentive ((9) x $3 or $2.50)	$	0	
11. Recorded incentive paid by CEC	$		
12. Location of modules: House Roof, Roof (other structure) or Ground			H/O/G
13. Orientation of modules: (Degrees of South)			Degrees
14. Tilt angle of modules: (Degrees from horizontal)			Degrees
15. Concerns regarding orientation/tilt:			Y/N
16. Tracking array?:			Y/N
17. Comments:			
18. Solar Access Check - modules unshaded 9 am to 3 PM?			Y/N
Comments:			

II. Wind Energy System

1. Brand/Model Number of Wind Generator		
2. Generator CEC Certified/Same as in Reservation?		Y/N
3. Inverter/Charge Controller Brand/Model*:		
4. Inverter CEC Certified/Same as in Reservation*?		Y/N
5. Inverter Efficiency* (CEC)		%
6. Tower (generator hub) Height:		Feet
7. Potential Obstructions/Turbulence Factors?		Y/N
Comments:		

* If applicable

Part 2: Determine if system is operating properly

I. Photovoltaic System

1. Output wattage of array:		Watts
2. Solar radiation:		W/m-2
3. Ambient temperature:		F
4. System output wattage consistent with conditions?		Y/N

II. Wind Energy System

1. Output wattage of generator:		Watts
2. Wind conditions		
3. System output wattage consistent with conditions?		Y/N
4. Cumulative output of wind system to date (from inverter, if applicable)		kWh

Part 3: Determine if system installed in compliance with regulations

1. Local building jurisdiction approved permit?			Y/N
2. Issuing Authority			
3. Date of Permit Issue/Approval	Issue	Approval	
4. System grid-tied to IOU (Check meter or bill):			Y/N
5. Did customer receive 5 year written warranty?			Y/N

Part 4: Photograph record

Photo 1:	Prints
Photo 2:	
Photo 3:	
Photo 4:	Slides
Photo 5:	

Part 5: Verifier Comments

Verifier Comments:

Is customer interested in participating in our detailed monitoring program?		Y/N
Is site a "good fit" for the monitoring program (ease of meter installation)?		Y/N

Verification by:_________________________ Date:

Part 6: Customer Comments/Quotes

Appendix C

Site Verification Data Spreadsheets

Phase I Verification Spreadsheets

Phase II Verification Spreadsheets

Phase III Verification Spreadsheets

Appendix D

Site Pictures and Images

APPENDIX D: Photo Indexes

Pictures of systems verified during Phase I were taken with a conventional film camera and with a digital camera. Original prints and slides from the film camera were delivered along with a previous verification report completed in 1999. A Phase I picture index and thumbnail images are included in this appendix for reference purposes.

Print Photo Index – Phase I

Index Sheet Number	Photo Number	Reservation ID Number
1	1	168
	2 – 4	63
	8 – 11	160
	12 – 15	159
	16 – 19	44
	20 – 23	232
2	1 – 2	21
	3 – 5	129
	9 – 10	76
	11 – 12	49
	14 – 16	134
	17 – 18	47
	19 – 22	42
	23 – 25	168
3	1 – 2	231
	3 – 5	203
	6 – 8	170
	9 – 10	107
	13 – 16	166
	20 – 21	18
	24 – 25	21
4	8 – 11	102
	12 – 13	69
	14	165
	15 – 16	165
	17 – 19	65
	20 – 23	81
	24 – 25	71

Site Verification
Photo Index – Phase I (Continued)

Digital photos of systems verified during Phase I are identified below. These files are saved on a CD that is being delivered with this report. In some cases participants raised confidentiality concerns and asked that pictures not be taken of their systems. In other instances participants requested that they be contacted for specific approval if their pictures might be released to the public. Pictures of these latter systems were delivered to the Commission separately.

ID11_Power_Center.JPG
ID11_PV_Array1.JPG
ID11_PV_Array2.jpg
ID12_Power_Center.JPG
ID12_PV_Array.JPG
ID12_PV_Array_Street.JPG
ID145_Dirty_Panels.JPG
ID145_MicrowavePhoneRelay.JPG
ID145_Power_Center.JPG
ID145_PV_Array1.JPG
ID145_PV_Array2.JPG
ID145_PV_Array_Side.JPG
ID145_Site_Shot.JPG
ID145_Surrounding_Wind_Farm.JPG
ID146_Power_Center.JPG
ID146_PV_Array1.JPG
ID146_PV_Array2.JPG
ID161_Inverter_Chicken_Wire.JPG
ID161_PV_Array1.JPG
ID161_PV_Array2.JPG
ID161_PV_Array3.JPG
ID161_PV_Manual_Adj_Legs.JPG
ID22_Inverter.JPG
ID22_PV_Array_Back.JPG
ID22_PV_Array_Front.JPG
ID22_PV_Array_Side1.JPG
ID22_PV_Array_Side2.jpg
ID25_Stack_Shade.jpg
ID26_PV_Array.bmp
ID26_PV_Array.JPG
ID26_PV_Array1.jpg
ID26_PV_Array_Backside1.JPG
ID26_PV_Array_Backside2.jpg
ID26_PV_Array_From_SW.JPG
ID26_PV_Array_Side1.JPG
ID26_PV_Array_Side2.jpg
ID27_Inverter1.jpg
ID27_Inverter2.JPG
ID28_Inverters_East_Arcade.JPG
ID28_Park_Entrance.JPG
ID28_PV_Arrays_Aerial.bmp
ID28_PV_Arrays_Aerial.jpg
ID28_PV_Array_Coaster.JPG
ID29_Inverters1.jpg
ID29_Inverters2.jpg
ID29_PV_Array1.bmp
ID29_PV_Array1.jpg
ID29_PV_Array2.jpg
ID29_PV_Array_Shade_Trees1.JPG
ID29_PV_Array_Shade_Trees2.jpg
ID29_PV_Array_Underside.JPG
ID30_PV_Array1.JPG
ID30_PV_Array2.JPG
ID30_PV_Module_Label.JPG
ID30_PV_Self_Shading.JPG
ID30_PV_Tree_Shading.JPG
ID70-121_Battery_Box.JPG
ID70-121_Inverter.JPG
ID70-121_PV_Array.JPG
ID70-121_PV_Array_Street.JPG
ID85-242_Power_Center.JPG
ID85-242_PV_Array1.JPG
ID85-242_PV_Array2.JPG
ID85-242_PV_Array_Backside.JPG

Site Verification
Photo Index – Phase II

Digital photos available for Phase II sites are identified below. These files are saved on a CD that is being delivered with this report.

ID206_PV_Array.jpg
ID206_PV_Array2.jpg
ID221_PV_Array.jpg
ID230_PV_Array.jpg
ID233_PV_Array1.jpg
ID233_PV_Array2.jpg
ID233_PV_Array3.jpg
ID245_Tracking_Arrays.jpg
ID250_PV_Array1.jpg
ID250_PV_Array2.jpg
ID274_PV_Array.jpg
ID286_PV_Array.jpg
ID329_Power_Center.jpg
ID329_PV_Arrays.jpg
ID379_PV_Array.jpg
ID388_Tracking_Arrays.jpg
ID398_Power_Center.jpg
ID398_Tracking_Array.jpg
ID409_PV_Array.jpg
ID409_PV_Array2.jpg

Site Verification
Photo Index – Phase III

Digital photos available for Phase III sites are identified below. These files are saved on a CD that is being delivered with this report. In some cases participants raised confidentiality concerns and asked that pictures not be taken of their systems. In other instances participants requested that they be contacted for specific approval if their pictures might be released to the public. In another case a participant requested that he be provided with a copy of any public material using pictures of his system. Pictures of these latter systems were delivered to the Commission separately.

ID1316_Disconnect_AC.jpg
ID1316_Inverter_Label.jpg
ID1316_Power_Center1.jpg
ID1316_Power_Center2.jpg
ID1316_Power_Center3.jpg
ID1316_PV_Array_Street1.jpg
ID1316_PV_Array_Street2.jpg
ID1316_PV_Array_Street3.jpg
ID1316_PV_Array_Street4.jpg
ID1316_PV_Array_Street5.jpg
ID1316_PV_Array_Street6.jpg
ID1316_PV_Array_Street7.jpg
ID1316_PV_Array_Street8.jpg
ID1316_PV_Array_Street9.jpg
ID1316_PV_Array1.jpg
ID1316_PV_Array2.jpg
ID1316_PV_Array3.jpg
ID1316_PV_Module.jpg
ID1316_PV_Module_Label1.jpg
ID1316_PV_Module_Label2.jpg
ID1363_Inverter.jpg
ID1363_Power_Center1.jpg
ID1363_Power_Center2.jpg
ID1363_Tower.jpg
ID1363_Turbine.jpg
ID1363_Wind_Distance.jpg
ID1471-2562_Disconnect_AC.jpg
ID1471-2562_GTI.jpg
ID1471-2562_GTI_Label.jpg
ID1471-2562_Inverter_Label1.jpg
ID1471-2562_Inverter_Label2.jpg
ID1471-2562_Power_Center.jpg
ID1471-2562_PV_Array.jpg
ID1471-2562_PV_Array_Shading.jpg
ID1471-2562_PV_Trackers.jpg
ID1471-2562_Tower.jpg
ID1471-2562_Tower_Detail.jpg
ID1471-2562_Tracker_Closeup.jpg
ID1471-2562_Tracker_Concrete.jpg
ID1471-2562_Turbine1.jpg
ID1471-2562_Turbine2.jpg
ID1471-2562_Turbines_Street.jpg
ID1654-1655_Mount_PV1.jpg
ID1654-1655_Mount_PV2.jpg
ID1654-1655_Mount_PV3.jpg
ID1654-1655_PV_Array.jpg
ID1654-1655_PV_Modules.jpg
ID1654-1655_Turbines.jpg
ID1654-1655_Turbines_Trees1.jpg
ID1654-1655_Turbines_Trees2.jpg
ID2066_Array_DistantView.jpg
ID2066_Array_FromBackyard.jpg
ID2066_ChargeController.jpg
ID2066_ElecMeter&PVBreakerBox.jpg
ID2066_ElecMeter_Closeup.jpg
ID2066_FrontOfHouse.jpg
ID2066_House_RoofWherePVIs.jpg
ID2066_Inverter&BatteryBox.jpg
ID2066_Inverter_DisplayOutput.jpg
ID2066_Inverter_Wiring2.jpg
ID2066_Inverter_Wiring3.jpg
ID2066_Inverter_WiringCloseup1.jpg
ID2066_InverterBoxCloseToSpaPump.jpg
ID2066_InverterInBox.jpg
ID2066_PVDedicatedBreakerPanel.jpg
ID2134_Disconnect_AC.jpg
ID2134_Inverter_East-Left_325PM.jpg
ID2134_Inverter_East-Left_356PM.jpg
ID2134_Inverter_Label.jpg
ID2134_Inverter_West-Right_325PM.jpg
ID2134_Inverter_West-Right_356PM.jpg
ID2134_Inverters.jpg
ID2134_Inverters1.jpg
ID2134_Inverters2.jpg
ID2134_PV_Array_Carport1.jpg
ID2134_PV_Array_Carport2.jpg
ID2134_PV_Array_Carport3.jpg
ID2134_PV_Array_Carport4.jpg
ID2134_PV_Array_Carport5.jpg
ID2134_PV_Array_Carport6.jpg
ID2134_PV_Array_Carport7.jpg
ID2134_PV_Array_House1.jpg

ID2134_PV_Array_House2.jpg
ID2134_PV_Array_House3.jpg
ID2134_PV_Array_House4.jpg
ID2134_PV_Array_Street1.jpg
ID2134_PV_Arrays1.jpg
ID2134_PV_Arrays2.jpg
ID2134_PV_Arrays3.jpg
ID2134_PV_Module_Label1.jpg
ID2134_Sky_Clouds1.jpg
ID2134_Sky_Clouds2.jpg
ID2271_Antennae.jpg
ID2271_Conduit.jpg
ID2271_Module_Mount.jpg
ID2271_PV_Array1.jpg
ID2271_PV_Array2.jpg
ID2271_PV_Module.jpg
ID2271_Roof_Mount1.jpg
ID2271_Roof_Mount2.jpg
ID2271_Roof_Wiring.jpg
ID2308_Elec_Boxes.jpg
ID2308_Inverter.jpg
ID2308_PV_Array1.jpg
ID2308_PV_Array2.jpg
ID2308_PV_Array3.jpg
ID2308_PV_Module.jpg
ID2308_Tracker1.jpg
ID2308_Tracker2.jpg
ID2390_PV_Array.jpg
ID2390_PV_Module.jpg
ID2396_Battery_Monitor.jpg
ID2396_Charge_Controllers.jpg
ID2396_Combiner.jpg
ID2396_Conduit1.jpg
ID2396_Conduit2.jpg
ID2396_Inverter_Label.jpg
ID2396_Inverter1.jpg
ID2396_Inverter2.jpg
ID2396_Power_Center.jpg
ID2396_PV_Array_Street.jpg
ID2396_PV_Module.jpg
ID259_PV_Array.jpg
ID259_Power_Center.jpg
ID278_Front_PV_Array.jpg
ID278_Roof_PV_Array.jpg
ID2941_Conduit1.jpg
ID2941_Conduit2.jpg
ID2941_Conduit3.jpg
ID2941_Disconnect_AC1.jpg
ID2941_Disconnect_AC2.jpg
ID2941_Inverter_Label1.jpg
ID2941_Inverter_Label2.jpg
ID2941_Mount_Roof1.jpg
ID2941_Mount_Roof2.jpg
ID2941_Mount_Roof3.jpg
ID2941_Power_Center.jpg
ID2941_PV_Array1.jpg
ID2941_PV_Array2.jpg
ID2941_PV_Module.jpg
ID2941_Roof_Vent.jpg
ID3310_ArrayOnCarport.jpg
ID3310_Arrays.jpg
ID3310_Arrays_RearView.jpg
ID3310_BatteryBox.jpg
ID3310_BatteryBox2.jpg
ID3310_ElecMeter&SolarSubPanel.jpg
ID3310_InverterBypass.jpg
ID3310_InverterCabinet.jpg
ID3310_InverterLabel.jpg
ID3310_PanelLabel_2PanelArray.jpg
ID3310_PanelLabel_2PanelArray_2.jpg
ID3310_PanelLabel_8PanelArray.jpg
ID3333_PV_Array1.jpg
ID3333_PV_Array2.jpg
ID3333_PV_Array3.jpg
ID3641_Antennae.jpg
ID3641_Chimney.jpg
ID3641_Conduit_Wall.jpg
ID3641_Disconnect_AC.jpg
ID3641_Mount_Detail1.jpg
ID3641_Mount_Detail2.jpg
ID3641_Mount_Detail3.jpg
ID3641_Power_Center.jpg
ID3641_PV_Array1.jpg
ID3641_PV_Array2.jpg
ID3641_PV_Array3.jpg
ID3641_PV_Module.jpg
ID3641_Trees.jpg
ID3885_Batteries.jpg
ID3885_Combiner1.jpg
ID3885_Combiner2.jpg
ID3885_Combiner3.jpg
ID3885_Combiner4.jpg
ID3885_Combiner5.jpg
ID3885_Conduit_Roof1.jpg
ID3885_Conduit_Roof2.jpg
ID3885_Conduit_Wall.jpg
ID3885_Disconnect_DC.jpg
ID3885_Inverter.jpg
ID3885_Inverter_Label.jpg
ID3885_Module_Close.jpg
ID3885_PV_Array.jpg
ID3885_PV_Module.jpg
ID3885_Roof_Combiners.jpg
ID3885_Roof_Mount.jpg
ID440_PV_Array.jpg
ID440_Power_Center.jpg
ID444-445_PV_Wind.jpg
ID4500_Inverters.jpg
ID4500_Mount_Module1.jpg
ID4500_Mount_Module2.jpg
ID4500_Power_Center.jpg
ID4500_PV_Array.jpg

ID4500_PV_Module.jpg
ID4582_Module_Detail1.jpg
ID4582_Module_Detail2.jpg
ID4582_Module_Detail3.jpg
ID4582_PV_Array.jpg
ID4582_Roof_Detail1.jpg
ID4582_Roof_Detail2.jpg
ID466_Power_Center.jpg
ID466_PV_Arrays.jpg
ID4661_Array_Eastern.JPG
ID4661_Array_Western.JPG
ID4661_Arrays_Both.JPG
ID4661_BackupDedicatedCircuits.JPG
ID4661_BatteryCase.JPG
ID4661_DedicatedCircuitPanelCover.JPG
ID4661_ElectricMeter.JPG
ID4661_EMeter&SolarDisconnect.JPG
ID4661_InverterCoverCloseup.JPG
ID4661_InverterExternalIndicatorLights.JPG
ID4661_InverterPanel_Entire.JPG
ID4661_InverterPanel_Left.JPG
ID4661_InverterPanel_Middle.JPG
ID4661_InverterPanel_Right.JPG
ID4661_Inverters&Batteries.JPG
ID4661_MountingBracket.JPG
ID4661_SinglePanelCloseup.JPG
ID4661_SolarDisconnect.JPG
ID4661_WholeHouse.JPG
ID4661_WholeHouse_WithComments.jpg
ID479_Power_Center.jpg
ID479_PV_Array.jpg
ID489_Power_Center.jpg
ID489_PV_Array.jpg
ID496_Power_Center.jpg
ID496_PV_Array_Back.jpg
ID496_PV_Array_Side.jpg
ID496_PV_Array_Street.jpg
ID506_PV_Array.jpg
ID506_Power_Center.jpg
ID615_Power_Center.jpg
ID615_PV_Array.jpg
ID615_PV_Array_Street.jpg
ID635_PV_Array_Back.jpg
ID635_PV_Array_Front.jpg
ID635_PV_Array_Side.jpg
ID669_PV_Array1.jpg
ID669_PV_Array2.jpg
ID689_Power_Center.jpg
ID689_PV_Array.jpg
ID717_PV_Array.jpg
ID726-727_Power_Center.jpg
ID726-727_PV_Array.jpg
ID726-727_Turbines.jpg
ID752_PV_Array.jpg
ID778_Back_PV_Array.jpg
ID778_Front_PV_Array.jpg
ID778_Power_Center.jpg
ID778_Street_PV_Array.jpg
ID801_PV_Tracker1.jpg
ID801_PV_Tracker2.jpg
ID830_PV_Array1.jpg
ID830_PV_Array2.jpg
ID832_PV_Array1.jpg
ID832_PV_Array2.jpg
ID833_PV_Array1.jpg
ID833_PV_Array2.jpg
ID833_Power_Center.jpg
ID883_Inverter.jpg
ID883_PV_Array1.jpg
ID883_PV_Array2.jpg
ID911_PV_Array1.jpg
ID911_PV_Array2.jpg